

A NEW GENUS OF GRASS CICADAS (HEMIPTERA: CICADOIDEA: CICADIDAE)
FROM QUEENSLAND, WITH DESCRIPTIONS OF THEIR SONGS

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Five species of small (≤ 15 mm total length) grass cicadas are described in *Graminitigrina* gen. nov., of the subfamily Cicadettinae, Tribe Cicadettini. Three species occur in northern Queensland, two of which, *G. karumbae* sp. nov. and *G. bowensis* sp. nov., have distributions spanning linear distances of approximately 655 and 830 km respectively. The third, *G. triodiae* sp. nov., is restricted to the Burra Range within White Mountains National Park. Two species, *G. bolloni* sp. nov. and *G. carmarvonensis* sp. nov., occur in southern to central Queensland; *G. carmarvonensis* restricted to the Mount Moffatt–Chesterton Range region of Carnarvon National Park, and *G. bolloni* within the area between Bollon, 60 km north of St George, to near Jericho, spanning a linear distance of approximately 505 km. The calling songs of each species are shown to be distinct, and constitute valuable taxonomic characters. Additional song types recognised and documented are: the ‘alarm (stress) song’, the ‘short song’ (both types recorded from *G. bowensis*) and the ‘ratchet song’, this common to four of the species described here. The calling song of *G. bowensis* is shown to vary in some temporal characteristics over at least part of its known distribution. □ *Cicadas, calling songs, chirping songs, Queensland, song analyses, taxonomy.*

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This work results from ongoing systematic collecting of cicadas throughout Queensland. Such surveys continue to uncover previously undescribed smaller cicadas occurring in a wide range of woodland and grassland habitats (e.g. Ewart, 2005). An important adjunct of the collection of specimens is the aural recording of their songs, which are valuable taxonomic tools (e.g. Young, 1972; Ewart, 1988, 1989, 1998, 2005; Ewart & Popple, 2001; Popple, 2003; Simões et al., 2000; Sueur, 2002; Pinto-Junia et al., 2005; Quartau & Simões, 2006; Seabra et al., 2006). In the field, calling songs provide an efficient means for identifying known species, and recognition of new species and species complexes. This paper describes five new and very distinctive species that are confined to rough grassland, low heath and spinifex, commonly associated with open forest, and which belong to a new genus. The distances over which the two most northern species have been collected, and aurally recorded, provide useful data in evaluating possible regional variation in morphology and song characteristics.

ABBREVIATIONS. *Institutions.* ANIC, Australian National Insect Collection, Canberra; AE, private collection of A. Ewart, Caloundra; BMNH, the

Natural History Museum, London; JM, private collection of J. Moss, Brisbane; KLD, private collection of K. L. Dunn, Canberra; LWP, private collection of L.W. Popple, Brisbane; MSM, private collection of M.S. Moulds, Kuranda; QM, Queensland Museum, Brisbane. *Collectors and general.* NP, National Park; Rd, Road; Rec, recorded (= aural/electronic song recording); sp, species; spec and Spm, specimen; CB, C.J. Burwell; AE, A. Ewart; BJM, B.J. Moulds; MSM, M.S. Moulds; LWP, L.W. Popple. *Morphological.* BL, total body length; FWL, fore wing length; HW, head width; PW, pronotum width; AW, abdomen width; FWL/BR, fore wing length/breadth ratio.

MATERIALS AND METHODS

Anatomical terminology follows Moulds (2003, 2005) for general body shape and wing characters, Dugdale (1972) and Moulds (2005) for genitalia, de Boer (1999) for opercula, and Simmons and Young (1978), Dugdale (1972) and Bennet-Clark (1977) for timbals. The timbal long ribs are referred to sequentially as ribs numbered 1 to 5, with rib 1 being the most posterior (adjacent to timbal plate). The higher

TABLE 1. Comparison of selected morphological characters, with specific reference to males, of genera most similar to *Graminitigrina*

Genera	<i>Graminitigrina</i>	<i>Pauropsalta</i>	<i>Cicadetta celis</i> + (Type sp. new genus)	<i>Urabinana marshalli</i> + (Type sp. new genus)	<i>Pauropsalta basalis</i> + (Type sp. new genus)	<i>Pauropsalta eyrei</i> + (Type sp. new genus)
Total body length (mm) (♂ and ♀)	10.7-15.0	11.7-24	12.5-26	9.0-16	10.7-12.4	13.2-23.4
Abdomen:						
(i) General shape (dorsal view)	Slightly to distinctly bulbous (anteriorly)	Gently tapered distally*	Gently tapered distally from tergites 2 to 8*	Slightly bulbous between tergites 2 to 4 (or 5), tapering rapidly thereafter*	Relatively even from tergites 2 to 6, tapering in rounded outline rapidly thereafter	Relatively gentle narrowing between tergites 2 to 6 (or 7), thereafter narrowing rapidly, especially at tergite 8.
(ii) Lateral width of tergite 3 relative to between auditory capsules	Slightly wider (most common) to nearly equal	Similar width	Slightly narrower in width*	Approximately equal	Slightly wider	Similar width
(iii) Colour	Yellow, pale yellow brown, reddish brown with conspicuous dorsal black fascia	Predominantly black ± reddish-brown to yellow-brown along tergite posterior margins*	Orange, yellow-brown, pale to medium brown	Variable; pale brown, orange yellow, green; black dorsal fascia in non-black species	Predominantly pale brown to reddish brown*	Pale brown to orange, yellow-orange; pale green
(iv) Width across auditory capsules relative to lateral pronotal margins	> than pronotum	Similar to, or slightly > than pronotum	Similar to, or slightly wider than pronotum	> than pronotum	> than pronotum	Approximately equal*
Head:						
(i) Width (including eyes) relative to lateral pronotal margins	Similar width	Similar to, or slightly wider than pronotum	Slightly wider than pronotum*	Maybe both < or > than pronotum width	> pronotum*	> pronotum*
(ii) Rostrum length (relative to coxae)	Extend to posterior margin of mid coxae	To mid coxae or just beyond mid coxae	Extend to hind coxae*	Just beyond mid to near hind coxae*	Reaches almost to hind coxae*	Reaches to base of mid coxae
Hind wings:						
(i) Number of apical cells	5 (less commonly 4)	5 (less commonly 6)	6 (rarely 5)*	4 to 6 (variable), 5 most common	5	6*
(ii) Infuscations (brown)	Weak within area of plaga (in anal lobe)	Small, distinct at distal end of vein 2A extending to wing margin*	None*	None*	Weak adjacent to distal end of vein 2A, extending either side along anal lobe margin, also in plaga	Absent to extremely faint adjacent to distal termination of vein 2A and adjacent margins
(iii) Size of anal lobe relative to cubital cell 1	Markedly wider than cubital cell 1	Much wider than cubital cell 1	Wider than cubital cell 1, but not markedly so*	Similar in breadth, or slightly broader than cubital cell 1*	Much wider than cubital cell 1	Much wider than cubital cell 1
Opercula:						
(i) General shape and curvature inwards towards abdominal midline	Rounded along distal to medial margin; tends to be elongated, and inwardly curved towards midline	Somewhat elongated, terminally rounded, inclined inwards to abdominal midline	Somewhat elongated and sickle-shaped, markedly curved inwards to midline distally; markedly undulated*	Broad and rounded along medial to distal margins*	Broad, strongly inclined inwards towards midline; moderately acutely rounded distally*	Relatively elongated and curved along distal to medial margins towards midline; narrowed rounded termination*
Timhals:						
(i) Fusion of long ribs ventrally	1 to 3 most common (1 to 4 less common)	0 to 4 (most commonly 2 or 3)	1 to 2 nearly fused, or completely fused*	1 to 3 fused or unfused	Not fused*	1 to 2 fused (rarely 1 to 3)
(ii) Fusion of long ribs to basal spur	1 to 3 fused	Usually 1 to 4 (rarely 1 to 2 or 3) fused	1 to 4 fused*	1 to 3 always fused; 4 also commonly fused	1 to 3 fused	1 to 4 fused*

Table 1 continued...

Genera	<i>Graminitigrina</i>	<i>Pauropsalta</i>	<i>Cicadetta celis</i> + (Type sp. new genus)	<i>Urabunana marshalli</i> + (Type sp. new genus)	<i>Pauropsalta basalis</i> + (Type sp. new genus)	<i>Pauropsalta eyrei</i> + (Type sp. new genus)
Genitalia:						
(i) Claspers	Robust; sharp, pointed hooked terminations; not clearly exposed outside pygofer in lateral view	Well developed, robust, terminally hooked processes; not always visible outside pygofer in lateral view	Robust; in ventral view tapering to a blunt point, apically wide part, basally adjacent	Very robust, protruding in lateral view; terminally hooked*	Relatively small, only just visible in lateral view, hooked terminally*	Somewhat robust, small hooked claspers, not clearly exposed outside pygofer lateral view
(ii) Upper pygofer lobes	Enlarged extended posteriorly beyond pygofer; terminations tend to curve dorsally	Upper lobes enlarged, undivided, and flat	Significantly elongated laterally along pygofer, as finger-like (flattened or cylindrical) processes, rounded terminally*	Conspicuous, rounded, not markedly extended*	Bifurcate, extended ventrally, the lower part tooth-like and sharply pointed*	Extended into blinker-like processes with flattened termination in lateral view
(iii) Lower pygofer lobes	Clearly developed, rounded in lateral view, with inward pointing flat triangular extensions	Clearly developed	Robust, elongated along pygofer margin, rounded on outer margins, concave on inner margins; clearly separated from upper lobes*	Clearly visible in lateral view, smaller than upper lobes*	Present; but subdued in lateral view, gently curved*	Conspicuous, acutely to sharply tapering and posteriorly pointing.
(iv) Inner pygofer lobes	Prominent, somewhat rounded and bulbous	Distinctly developed	Not clearly developed in lateral view*	Clearly developed, broadly rounded, visible in lateral view	Strongly developed, acutely tapering, declivous, posteriorly inclined*	Slightly to conspicuously bulbous and raised in lateral view
(v) Dorsal beak	Inconspicuous	Acute, prominent, pointed apically*	Prominent, acute, pointed apically*	Very strongly developed, curved in lateral view*	Strongly developed, downward curving in lateral view, sharply pointed*	Prominent, sharply pointed, slightly curved in lateral view*
(vi) Aedeagus, endotheca	Long sclerotised endotheca, curved (to broad U-shape in some species), ornamented apically	Long sclerotised endotheca, often apically ornamented*	Theca recurved distally into an exaggerated U-shape*	Endotheca broad tube-like, straight to very gently curved in lateral view; no ventral support*	Endotheca gently curved*	Gently curved endotheca, apically enlarged and ornamented with a collar-like process and/or simple spines*
(vii) Pseudoparameres	Inconspicuous to absent	Usually prominent, joined to endotheca near base, often extending apically beyond endotheca*	Slender, delicate and long; aligned broadly with aedeagus*	Short and very broad in lateral view; joined to apex of endotheca*	Curved, apically tapering, attached dorsally and sloping ventrally across endotheca; longer than endotheca*	Dorsal, similar or shorter in length to endotheca; joining endotheca near basal plate, bifurcate and outward curving; distally tapering, acutely pointed*
Habitat:	Grassland, low heathland, usually associated with open woodland	Open woodland; inhabiting low to high branches*	Open woodland, especially in canopy*	Grassland, open and within open woodland	Low open woodland, shrubland, rough grassland	Open woodland, including urban*

+ These represent the type species of new genera proposed by M.S. Moulds (in prep, 2008). *Characters that differ from those of *Graminitigrina*

classification adopted in this paper follows Moulds (2005).

Measurements (in mm) are given as ranges and means (in parentheses). The head width is taken across the outer margins of the compound eyes; the pronotum width is the maximum width across the lateral margins; the abdomen width is measured across the auditory capsules. Fore wing length/breadth ratios are based on maximum lengths and breadths.

SONG RECORDINGS AND ANALYSES.

A number of recordings were made of single insects placed within plastic containers, 16.5 x 16.5 x 9.5 cm in size, in which were inserted small quantities of the grasses on which the insects were captured. A fine white cloth covering was placed over the top of the boxes, with strong artificial lighting (not fluorescence) immediately above. The lighting provided additional heat, and calling songs were usually readily induced from the insects. Temperatures within the containers were consistently 30–35°C during normal summer conditions. The recording microphone (Sennheiser model K6/ME66) was placed immediately above the containers, and recordings mostly made with a Sony Walkman cassette recorder WM-D6C model, using metal tapes; this recorder responds to near 18 kHz, with a linear response to at least 15 kHz.

The primary reasons for making recordings within containers relates to the highly wary behaviour, aurally soft songs, and sometimes erratic singing patterns of the described species, which make it impractical to place a microphone close enough, for long enough, to directly record meaningful song segments. This problem was in part circumvented in two species by use of a parabola (Telinga model with Telinga PRO 5 "Classic" microphone) allowing direct field recordings, and also by use of a collapsible, cylindrical net cage (38 cm long by 30 cm diameter) hung from convenient vegetation in the field. For *G. carnavonensis*, a Sony Minidisk recorder MZ-NH900 was used in PCM recording mode using the net cage. Alarm (stress) songs of *G. bowensis* were recorded from two locations when the insects were trapped in spider webs, and also constrained in a net. The direct field recording of the *G. bolloni* calling song (at Jericho, central Queensland) was made by L.W. Popple using a Marantz PMD670 Solid State recorder in conjunction with a Telinga parabola and PRO 6 microphone.

All computer analyses were performed by initial digitising through 16-Bit Terratec or SB Audigy 2ZS sound cards at 44.1 kHz sampling frequency, followed by processing with Avisoft SAS Lab Pro 4 software. Reverberation effects in container recordings have been recognised for some sharp pulses at time scales of ≤ 1 ms, causing some broadening of the pulses. An additional effect seen in some container recordings is the enhanced splitting of the dominant frequency peaks of the amplitude (and power) spectra into distinct frequency bands. As this is also evident in some field recordings, it is considered to be a real characteristic of some songs. This effect does, however, appear to be enhanced in container recordings, although not affecting the dominant frequency measurements (see below). Amplitude spectra were produced using a 556-point Fast Fourier Transform with Hamming window.

The amplitude/power spectra of *Graminitigrina* cicada songs, as in other cicadettine cicadas (e.g. *Crotopsalta*, Ewart, 2005), are complex with multiple distinct peaks occurring within the normally well defined envelope defining the dominant frequency maxima range. The individual peak amplitudes (although not frequencies) within this envelope are typically variable between songs of different insects of the same species. In order to determine a more reproducible frequency maximum for each spectrum, a "dominant frequency" parameter is used, this being the mean frequency of the total amplitude dominant frequency envelope as seen in the spectra. The extent of this envelope is shown in the amplitude spectra presented. This method allows more reproducible estimates of dominant frequencies, and also compensates for enhanced frequency splitting that may accompany container recordings. In addition to dominant frequencies, the amplitude spectra illustrated also list measured sideband frequencies (e.g. Bradbury and Vehrencamp, 1998). These are derived manually from frequency expanded segments of the spectra, using the automatic measuring cursors available in the Avisoft software. Sideband frequencies below about 300 Hz are reproducible in spectra from the same species. Above this frequency, the measured frequencies become progressively less reliable due to uncertainties in their correct identification and significance.

Following Ewart (2005), a modified terminology of Ragge and Reynolds (1998) is adopted for the description and analyses of the songs. Although the Ragge-Reynolds terminology was designed for orthopteran insects, there are



FIG. 1. *Graminitigrina bowensis* sp. nov. Dorsal view. Flagstaff Hill, Bowen. Total body length 13.7mm.

sufficient similarities in song structures to warrant extending the terminology to the cicada songs described here. The term **syllable** is used for discrete but relatively short (≤ 20 ms) pulse groupings that plausibly result from a single buckling movement (in and/or out) of one timbal, or both if synchronous; if the two timbals buckle alternately, without a time gap between, then two syllables may occur juxtaposed, as is believed to occur in eliciting phases within some of the cicadas described here. The same result may be attained, at least in principle, by a discrete inward, followed immediately by an outward click of a timbal; where, however, a small but discrete gap does occur in such a sequence between the syllables, the term **diplosyllable** is normally used for these syllable pairs. The term **echeme** is applied to the first order assemblage of syllables produced during continuous, repetitive buckling of the timbal pairs (i.e. ≥ 2 cycles of buckling without significant pause). Where two (or sometimes more) syllables are juxtaposed, these are termed **macrosyllables**, and are identified as echeme components in some songs described here. Time expanded waveform

and envelope plots reveal that the syllables are resolved into smaller (higher frequency) pulse groupings, here termed **hemisyllables**, although the precise resolution of these is sometimes ambiguous. The hemisyllables, with further time expanded detail, can be resolved into even higher frequency pulses, representing the fundamental frequency carrier waves of the song.

SYSTEMATICS

Family CICADIDAE Latreille

Subfamily CICADETTINAE Buckton

Tribe Cicadettini Buckton

***Graminitigrina* gen. nov.**
(Table 1)

TYPE SPECIES. *Graminitigrina bowensis* sp. nov.

INCLUDED SPECIES. *G. bowensis* sp. nov.; *G. karumbae* sp. nov.; *G. bolloni* sp. nov.; *G. carnarvonensis* sp. nov.; *G. triodiae* sp. nov.

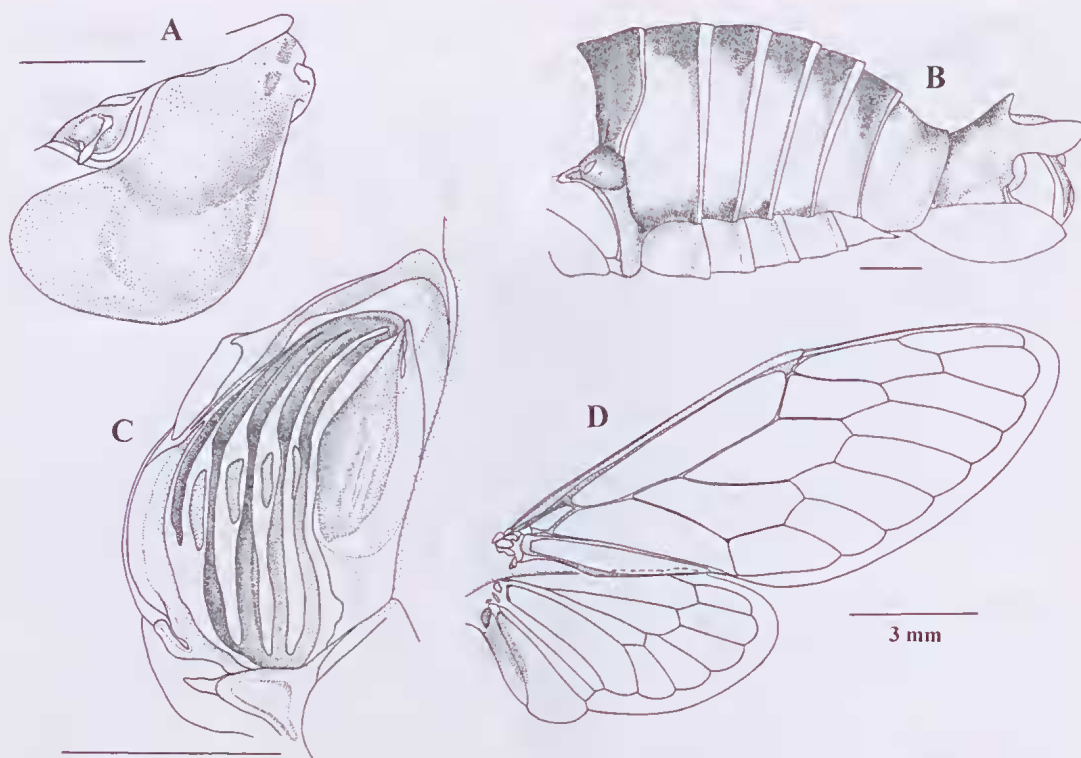


FIG. 2. *Graminitigrina bowensis* sp. nov. Flagstaff Hill, Bowen. A, right operculum; B, lateral abdomen; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

ETYMOLOGY. From the Latin *gramen* meaning grass, and *tigri-n* meaning tiger-like colouration. These together describe the cicadas as 'grass tigers', referring to their grassy habitat and conspicuous yellow-orange and black dominant colouration.

DIAGNOSIS. Very small cicadas, 10.7-15mm total body length. Head and thorax predominantly black and of similar width, except amplified (outwardly curved) lateral angles of pronotal collar projecting beyond outer margins of compound eyes. Abdomen dominantly yellow/yellow-brown/reddish to orange-brown, with dark brown to black dorsal patches along tergites, which give overall appearance of a dark longitudinal fascia. Male abdomen in dorsal view slightly bulbous anteriorly; width across tergite 3 subequal or slightly greater than width across auditory capsules; width across auditory capsules greater than (males) or similar to (females) width across lateral margins of pronotal collar. Sternites strongly convex, projecting below tergites in lateral view; abdominal venter lacking a medial darker fascia; sternite II with small, usually black, medial depression. Compound eyes clearly

separated from pronotum along their outer ventral margins; distance between lateral ocelli slightly less than, to equal to, distance between lateral ocellus and compound eyes. Rostrum extending to posterior margins of mid coxal, but not clearly beyond. Fore wing hyaline, relatively short and broad with length/breadth ratios between 2.40-2.68 (mean ratios for different species between 2.45-2.60); fore wing similar in length to total body length; pterostigma pale brown to pale red-brown; costal vein relatively even in width, with minor thickening proximally and slightly more pronounced thickening adjacent to node; costal vein very gently curved anteriorly; sclerotised area along anterior margin of costal vein very narrow and much thinner than costal vein thickness; costal and R+Sc veins fused; CuA intersecting M well beyond basal cell so that length of first section of inner margin of radial cell is one half to equal length of second section; 3 distal vein sections of M, that form inner margin of radial cell, unequal in length; cubital and medial cells of roughly similar size; 8 (very rarely 9) apical

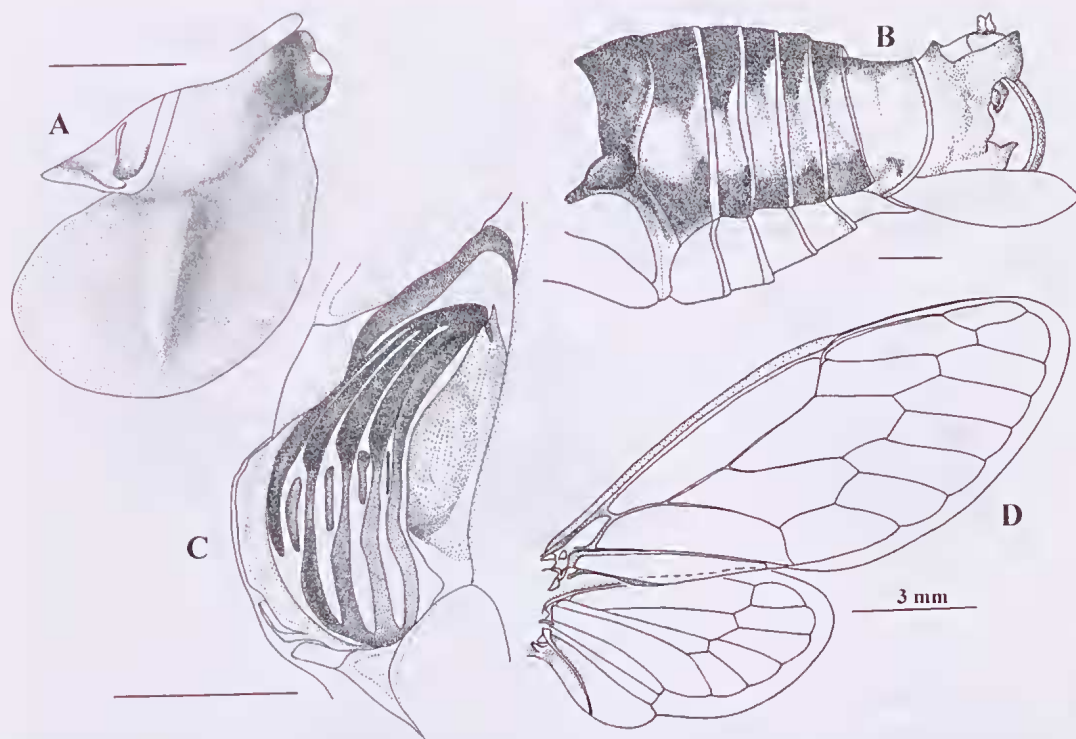


FIG. 3. *Graminitigrina bowensis* sp. nov. Einasleigh River crossing, 35km W. Mt Surprise. A, right operculum; B, lateral abdomen; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

cells that are approximately equal in length to ulnar cells (some longer, some shorter); basal membrane off-white opaque. Hind wings hyaline with 5, less commonly 4, apical cells; weak brown infuscation within anal cell 1; anal lobes markedly broader than cubital cell 1. Fore femora with 3 prominent erect spines, small additional spine distally in some specimens. Opercula moderately elongated roughly parallel to abdomen, more or less confluent with distal margin of tympanal cavity, normally very slightly overlapping distal tympanal margin; opercula inwardly curved towards abdominal midline in medial-distal area, distal and medial margins of opercula broadly rounded; broad dome developed across basal area towards crest; inner margins of operculae well separated; opercula of males developed asymmetrically around meracantha. Timbals with 5 well developed long ribs, the 5th rib reduced in length; ribs 1 to 3 fused ventrally and dorsally to well developed basal spur; 4 (less often 3) well developed short ribs; well developed dome on timbal plate with shallow and nearly vertically oriented grooves centrally. Pygofer with prominent, extended upper lobes

which dominate pygofer between inner lobe (secondary basal lobe) and dorsal beak, these nearly flat with gently undulating and concave curvature on inner faces; in lateral view, upper lobes broad, paddle-shaped, often decurved, and extending to or beyond anal styles; clearly developed lower lobes with small inward pointing triangular extensions; prominent rounded inner lobes, roughly triangular in shape and visible in lateral view; well developed robust claspers with sharply-pointed, hooked terminations, not always protruding outside pygofer in lateral view; dorsal beak inconspicuous; median lobe of uncus small, duck-bill shaped, not dominant; theca characteristically long and sclerotised, curved and often terminally ornamented, protruding from pygofer; pseudoparameres small to absent; aedeagal basal plate undulated in lateral view, broadly Y-shaped in dorsal view, with functional membranous 'hinge'.

Table 1 provides a comparative summary of selected morphological characters of related genera which may be superficially confused with *Graminitigrina*.

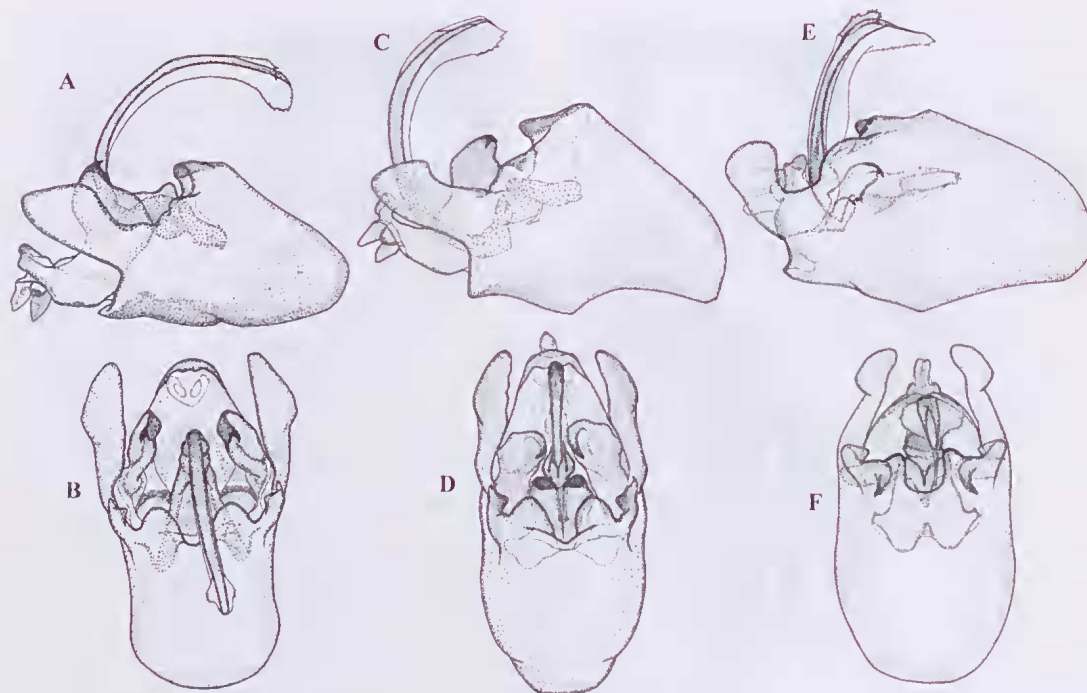


FIG. 4. *Graminitigrina bowensis* sp. nov. Pygofer and male genitalia, lateral (top) and ventral views (bottom). Specimens from Bowen (A, B); 58km SE Mt Surprise (C, D); Slaty Creek, S.W. Cloncurry (E, F). Length of pygofers, 3.3, 3.2 and 3.1 mm, respectively.

KEY TO SPECIES OF
GRAMINITIGRINA
(Based on males)

1. Timbal rib 5 (anterior rib) extending ventrally at least to dorsal end of adjacent anterior short rib, usually extending along half the length or more of short rib (Figs 2C, 3C, 6C, 7C); aedeagus with long theca recurved into broad U-shape with thin sclerotised wafer-like process, usually finely serrated, along inner curved surface; pseudoparameres absent (e.g. Figs 4A, 8A) 2
- Timbal rib 5 not extending ventrally to dorsal end of adjacent anterior short rib (Figs 9C, 13C) or anterior short rib absent (Fig. 11C); aedeagus with long, variably curved to recurved theca, also with thinly developed wafer-like process developed along inner curved surfaces; pseudoparameres present but sometimes small (Figs 10A, 12A, 14A)..... 3
2. Timbal rib 5 extending ventrally along anterior short rib from about a half to its entire length; no ventrally located short remnant of rib 5; rib 5 very close to, or partially in contact with dorso-anterior timbal margin (Figs 2C, 3C); maximum width across abdominal tergite 3 slightly greater than across auditory capsules; abdominal tergite 2 almost entirely black (Figs 2B, 3B) *G. howensis*
- Timbal rib 5 extending ventrally along anterior short rib to at most half its length, often less, but with a isolated remnant of rib 5 located ventrally; rib 5 close to, but not in contact with dorso-anterior timbal margin (Figs 6C, 7C); maximum width across abdominal tergite 3 similar to width across auditory capsules; abdominal tergite 2 not entirely black *G. karumbae*
3. Fore wings without obvious apical infuscation (Figs 9D, Pl. 2A); aedeagus gently curved except distal part of theca strongly recurved, hook-like; sclerotised wafer-like process on theca either absent or only developed apically *G. bolloni*
- Fore wings with weak to distinct infuscation apically (Figs 11D, 13D, Pl. 2C, E); aedeagus with gently curved theca, apex not strongly recurved; apex of theca either finely serrated or with complex sclerotised ornamentation (Figs 12A, 14A)..... 4
4. Fore wings with weak brown infuscation apically, extending from approximately apical cell 4 (Figs. 11D, Pl. 2C); 3 short timbal ribs between ribs 1 to 4 clearly developed, no short rib anterior to long rib 4; timbal rib 4 not fused ventrally to ribs 1-3 (Fig. 11C); prominent spikes on meracantha (Fig. 11A); aedeagus very gently curved and apically ornamented (Fig. 12A) *G. carnarvonensis*
- Fore wings with clearly developed apical infuscation extending (more weakly) to apical cell 5 and ulnar cells 1 and 2 (Figs 13D, Pl. 2E); timbal rib 4 fused ventrally to ribs 1-3; short timbal ribs between ribs 1 to 4 weakly developed; unusually large area of white resilin developed anteriorly to ribs 4 and 5 (Fig. 13C); meracantha spikes short (Fig. 13A); aedeagus with more strongly curved theca, apex slightly sinuous and unornamented *G. triodiae*

***Graminitigrina bowensis* sp. nov.**
(Figs 1-5, 15-24, Plate 1A-E, Table 2)

MATERIAL. HOLOTYPE: ♂, QMT13332, Flagstaff Hill, Bowen. NQ., 4 Mar 2003, AE, 20°00.93'S 148°15.97'E, Photog. Spm PS1048. **PARATYPES:** NORTH QUEENSLAND: 2♂, Flagstaff Hill, Bowen, Grass, 13.ii.1998, AE, 20°00.88'S 148°15.96'E, Recorded; 1♀, same data; 1♂, same data, 10.ii.1999, Recorded; 1♀, same data; 15♂, same data, 26.ii.2000; 1♂, same data, Recorded Specimen 1; 1♂, same data, Recorded Specimen 2; 1♂, Flagstaff Hill, Bowen, 7.ii.2002, 20°00.86'S 148°15.94'E; 2♂, Flagstaff Hill, summit area, Bowen, AE, 2.ii.2006. 20°00.93'S 148°15.97'E; 1♂, same data, Recorded (alarm call); 1♂, same data, 9.ii.2006; 1♂, E. side Einasleigh R., ~35km W. Mt Surprise, AE, 27.ii.2003, 18°11.15'S 144°00.77'E, Recorded; 1♂, same data, 2 iii.2003, Recorded; 1♂, 39.5km WNW Greenvale, (11.9km SE of Lynd jct., Lynd Hwy), Grass, AE, 3.iii.2003. 18°56.73'S 144°38.68'E; 1♂, Water Reserve, Croydon, NQ, Low Trees, AE, 28.i.2005, 18°11.35'S 142°14.61'E, Recorded; 1♂, 40.1km SSW Mt Surprise/Lynd Hwy. Jct., NQ, Grass, AE, 3.iii.2003, 18°28.93'S 144°44.79'E; 13♂, 5♀, 40.0km SSW Lynd-Mt Surprise Rd Jct., NQ, Grass, AE, 31.i.2005, 18°28.97'S 144°44.80'E; 1♂, same data, Recorded; 1♀, 49.4km SSW Mt Surprise/Lynd Hwy. Jct., NQ, Grass, AE, 3.iii.2003, 18°33.79'S 144°44.42'E (AE). 1♂, Flagstaff Hill, Bowen, 10.ii.1999, AE. 20°00.88'S 148°15.96'E; 1♀, Flagstaff Hill, summit area, Bowen, AE, 9.ii.2006. 20°00.93'S 148°15.97'E (ANIC). 1♂, Flagstaff Hill, summit area, Bowen., AE, 9.ii.2006. 20°00.93'S 148°15.97'E (BMNH). 1♂, Flagstaff Hill, summit area, Bowen, AE, 9.ii.2006. 20°00.93'S 148°15.97'E; 11♂, 13♀, Slaty Creek, S. of Cloncurry, 6.i.2001, 20:53:19S 140:20:45E, MSM and BJM (MSM).

DESCRIPTION (MALE). Figs 1-4, Pl. 1A-D. *Head.* Supra-antennal plate, vertex, mandibular plate and genae predominantly shiny black, covered by short golden pubescence (supra-antennal plate only) and longer yellow-silver pubescence; pale sandy-brown triangular fascia extending posteriorly from median ocellus, widening towards and extending to pronotal margin; small pale sandy-brown patches on antennal pedicels extending laterally along anterior margin of supra-antennal plate to postclypeal margin. Ocelli rose-red. Compound eyes dark brown. Postclypeus shiny black with sandy-brown margin extending around frons. Anteclypeus shiny black; rostrum brown grading to black apically. Antennae predominantly black with sandy-brown bases and brown apices.

Thorax. Pronotum shiny black, covered with patchy short silvery pubescence; ventro-lateral margins pale sandy-brown, broad pale sandy central fascia extending posteriorly from near

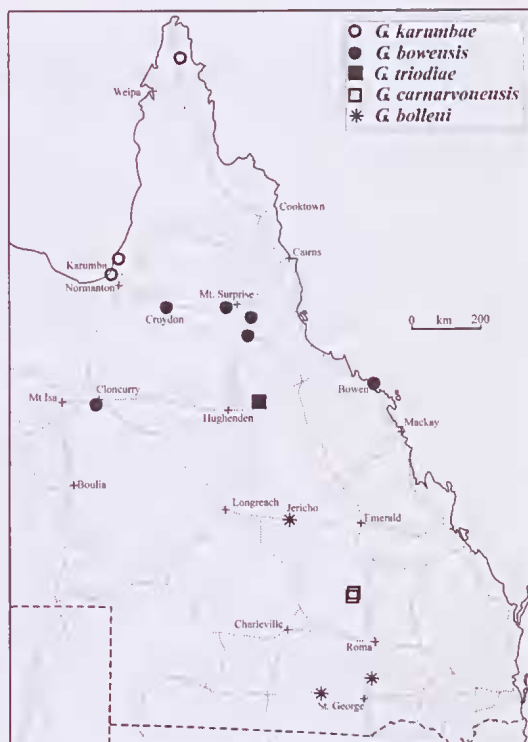


FIG. 5. Distribution records of the five described species of *Graminitigrina* in Queensland.

anterior margin, splaying out and fusing with pale sandy-brown pronotal collar; lateral angles of pronotal collar markedly ampliate, black with pale sandy-brown margins. Mesonotal submedian sigillae black, short, completely coalesced medially; narrow black fascia extending posteriorly from coalesced sigillae, progressively broadening and filling area between anterior arms of cruciform elevation (including scutal depressions), further bifurcating and extending as a narrow curved fascia between anterior and posterior arms of cruciform elevation; small pale central spot within fascia between anterior arms; lateral sigillae black, roughly triangular, posteriorly rounded, not reaching apices of anterior arms of cruciform elevation; margins of wing grooves, cruciform elevation, and areas surrounding lateral sigillae sandy-brown; mesonotum with sparse short silver pubescence, particularly strong near wing grooves

Wings. Venation pale off-white to pale brown, becoming darker brown apically; very narrow sclerotised brown anterior margin to costal vein. Hind wing with white opaque plaga extending along margins of veins 3A and 2A, but no

TABLE 2. *Graminitigrina bowensis* - summary of song parameters. Data compiled from separate recordings from seven insects (Bowen: field and container recordings), two insects (58km SE Mt Surprise; field and container recordings) and one insect from remaining localities (container recordings).

Locality	Bowen	Bowen	Bowen	Croydon	58 km SE Mt Surprise	Einiasleigh River Crossing	11.9 km SE of 'The Lynd' Hwy Jct.
Song Type	Calling Song	Stress Song ⁽⁵⁾	Ratchet Song ⁽⁵⁾	Calling Song	Calling Song	Stress Song ⁽⁵⁾	Short Song
1. Extended echeme ('buzzing')							
Total length (s)	1 to 4.5	-	-	-	-	-	-
Macrosyllable lengths (ms)	10.8(10.3-11.3) ⁽¹⁾	-	-	-	-	-	-
Syllable lengths (ms)	4.4-6.3	-	-	-	-	-	-
Hemisyllable lengths (ms)	1.0(0.35-1.9) ⁽¹⁾	-	-	-	-	-	-
2. Post-extended echeme phrases for Bowen locality: 'Normal' (standard) songs for other localities							
(a). Chirp phrases (short echemes + associated clicks)							
Repetition rates (s ⁻¹):	1.9(0.92-8) ⁽¹⁾	-	-	0.92(1.3-0.50)	1.8(1.2-2.4)	-	0.79(1.9-0.45)
Container	-	-	-	-	-	-	-
Repetition rates (s ⁻¹): Field	2.9(2.2-3.3) ⁽¹⁾	15.3(8-28)	-	-	-	21.7(18-29)	-
No. of initial clicks per chirp: Container	2.8(0-5) ⁽¹⁾	-	-	8.4(0-21)	2.2(0-4)	-	0
No. of initial clicks per chirp: Field	3.2(2-5) ⁽¹⁾	-	-	-	-	-	-
Chirp lengths (s): Container	0.34(0.15-0.46) ⁽¹⁾	-	-	0.61(0.24-1.6)	0.20(0.13-0.24)	-	0.76(0.21-1.7)
Chirp lengths (s): Field	0.24(0.18-0.33) ⁽¹⁾	0.031(0.009-0.044)	-	-	-	0.026(0.008-0.042)	-
(b). Single click phrases (single discrete macrosyllables)							
Macrosyllable lengths (ms)	13.7(12.7-14.4) ⁽¹⁾	10.8(10.6-11.0)	10.0(9.2-11.5)	11.3(11.1-11.4)	10.9(8.9-11.6)	9.5(9.1-9.9)	13.7(11.2-15.1)
Syllable lengths (ms)	6.1-7.2	4.9-6.0	4.5-6.5	5.3-5.8	5.4-6.2	4.4-5.3	6.7-7.2
Hemisyllable lengths (ms)	1.3(0.83-1.7) ⁽¹⁾	1.4(0.73-2.6)	1.2(0.92-1.4)	1.3(1.2-1.9)	1.3(1.0-1.6)	1.4(0.89-2.0)	1.5(1.3-2.2)
Interval between first two doublet pulses ⁽²⁾	4.1(3.0-5.2) ⁽¹⁾	3.7(3.6-3.9)	3.6(3.3-4.0)	3.9(3.4-4.1)	4.1(3.9-4.2)	3.4(3.3-3.5)	4.6(4.2-5.0)
Click repetition rates (s ⁻¹)	20-59	-	20-35	30-56	26-56	-	34-56
(c). Short echeme (chirp) phrases							
Macrosyllable lengths (ms)	10.2(10.0-10.5) ⁽¹⁾	11.0(10.7-11.4)	-	9.0(7.5-10.4)	10.9(10.7-11.9)	9.3(8.8-9.8)	11.2(10.5-12.9)
Syllable lengths (ms) ⁽³⁾	4.6-5.7	4.9-6.3	-	3.7-5.1	5.0-5.7	4.2-5.0	5.1-6.1
Hemisyllable lengths (ms)	1.4(0.66-2.0) ⁽¹⁾	1.4(0.96-2.6)	-	1.2(0.95-1.4)	1.2(0.91-1.6)	1.5(0.78-2.0)	1.4(0.94-1.9)
3. Pre-extended echeme phrases for Bowen locality							
(a). Chirp phrases (short echeme + associated clicks)							
Repetition rates (s ⁻¹)	2.0(2.5-1.5) ⁽¹⁾	-	-	-	-	-	-
No. of clicks between short echemes	7-10	-	-	-	-	-	-
Short echeme lengths (s)	0.30(0.21-0.49) ⁽¹⁾	-	-	-	-	-	-
Click repetition rates (s ⁻¹)	40.3(26-59) ⁽¹⁾	-	-	-	-	-	-
(b). Single click phrases (single discrete macrosyllables)							
Macrosyllable lengths (ms)	13.4(13.0-14.1) ⁽¹⁾	-	-	-	-	-	-
Syllable lengths (ms) ⁽⁴⁾	5.1-8.2	-	-	-	-	-	-
Hemisyllable lengths (ms)	0.66-1.8	-	-	-	-	-	-
Interval between first two doublet pulses	4.3(3.9-4.7) ⁽¹⁾	-	-	-	-	-	-
(c). Short echeme phrases							
Macrosyllable lengths (ms)	10.1(9.6-10.7) ⁽¹⁾	-	-	-	-	-	-
Syllable lengths (ms) ⁽³⁾	3.8-5.5	-	-	-	-	-	-
Hemisyllable lengths (ms)	0.39-1.9 ⁽¹⁾	-	-	-	-	-	-
4. Dominant frequency (kHz)							
	13.12 (12.64-13.56)	11.81	12.34	13.06	14.23	13.92	14.72
	(1) Figures are means and (ranges). (2) See Figs. 19c, d and 21c, d for doublet definitions. (3) Two per macrosyllable. (4) Two to three per macrosyllable. (5) Field recordings.						
							14.00

associated brown infuscation; 4 (less common) to 5 apical cells.

Legs. Fore coxae predominantly pale to medium brown with lozenge-shaped black to deep brown fasciae located centrally on lateral and anterior faces; mid and hind coxae pale to medium sandy-brown with localised deep brown to black patches subdorsally on lateral faces; fore and mid trochanters and femora sandy-brown to brown with narrow, medium to dark brown longitudinal fasciae; hind femora mainly pale brown; fore tibiae and tarsi medium to dark brown on anterior faces, pale sandy-brown on posterior faces; mid and hind tibiae and tarsi mostly pale sandy-brown to pale brown; claws pale brown, dark brown apically.

Opercula. Gently and broadly rounded along distal and medial margins, medial margin markedly curved inwards toward abdominal midline; colour sandy-brown except for 2 small, medium brown patches near basal crest of each operculum; basal area and lateral part of distal area of operculum very gently domed and longitudinally ridged, roughly parallel to midline of abdomen; spikes on mercantha small, not clearly overlapping opercula plate; distal operculum only just extending to anterior margin of sternite II in lateral view.

Timbals. Long ribs 1-3, (and usually 4) fused ventrally, and also dorsally to basal spur; rib 5 very close to and partly in contact with dorso-anterior margin of timbal; rib 5 extending ventrally to at least half way along (Slaty Creek specimens) or along entire length of adjacent, prominent anterior short rib; 4 clearly defined short ribs; dome on timbal plate with ridges (roughly parallel to ribs).

Abdomen. Maximum width across tergite 3 slightly greater than width across auditory capsules; in dorsal view, abdomen evenly decreasing in width from tergites 3-8. Dominant tergite colouration sandy/orange-brown, with reddish-brown colouration along the submedial to dorsal posterior margins adjacent to, but not extending across intersegmental membranes. Tergite 2 predominantly shiny black, black extending ventrally to and just below auditory capsules; small central brown area within auditory capsule, and also submedially within black area of tergite; black colouration extending anteriorly from tergite 2 to tergite 1, filling area between timbals; tergites 3-8 and pygofer each with dorsal black areas that narrow posteriorly within each tergite and become progressively narrower from one tergite to the

next, resulting in overall appearance of a strongly developed black fascia running dorsally along abdomen; tergites 3-6 each with small areas of black colouration ventro-laterally, largest and most intense on tergite 3, becoming smaller and weaker towards tergite 6; narrow, submedian red bands, each narrowing dorsally and ventrally, along posterior margins of tergites 3-7 of some specimens (notably those from 40km SSW Mt Surprise/Lynd Rd. Jct). Sternite II with median black area, otherwise sandy-brown; sternites III-VIII sandy-brown, slightly darker on sternite VIII.

Genitalia. (Fig. 4) Pygofer dominantly brown, black dorsally, including small dorsal beak. Upper pygofer lobes extended laterally with minor to no ventral curvature distally; apices of upper lobes relatively straight to very gently curved, posterodorsal 'corner' of apex relatively acutely rounded; aedeagus with long theca recurved into broad U-shape, apical ornamentation variable (notable in Slaty Creek specimens), with a thin, relatively narrow, lightly sclerotised, wafer-like process along inner curved theca margin, extending slightly beyond apex of theca, serrated distally; theca with ventral slit towards, and extending to apex, not always clearly visible; pseudoparameres absent.

FEMALE. (Pl. 1E) Very similar in colour and patterning to male, but with less black. Supra-antennal plate and vertex black, sandy-brown across entire anterior margin and extending to antennal pedicels. Postclypeus with broader sandy-brown margin that extends along transverse grooves and joins paler dorsal anterior margin of supra-antennal plate; mandibular plate and genae sandy-brown. Pronotum with central fascia broader and pale sandy-brown ventro-lateral colouration extending dorsally, thus reducing area of black colouration; scattered short golden pubescence. Mesonotum with submedian sigillae less extensively fused, and medial black fascia narrower and reaching, but not filling, area between anterior arms of cruciform elevation; lateral sigillae more irregular in outline and extensively broken by 'veinlets' of sandy-brown; rest of mesonotum, including cruciform elevation, sandy-brown. Fore coxae, trochanters, and femora dominantly sandy-brown, with erratic and incomplete darker brown fasciae on anterior faces; fore tibiae and tarsi, and mid and hind legs sandy-brown, apices of claws, and spines on fore femora, dark brown. Abdomen with dorsal black patches generally smaller; that on tergite 2 extending submedially; patches on 5-7 smaller and lighter, patch on tergite

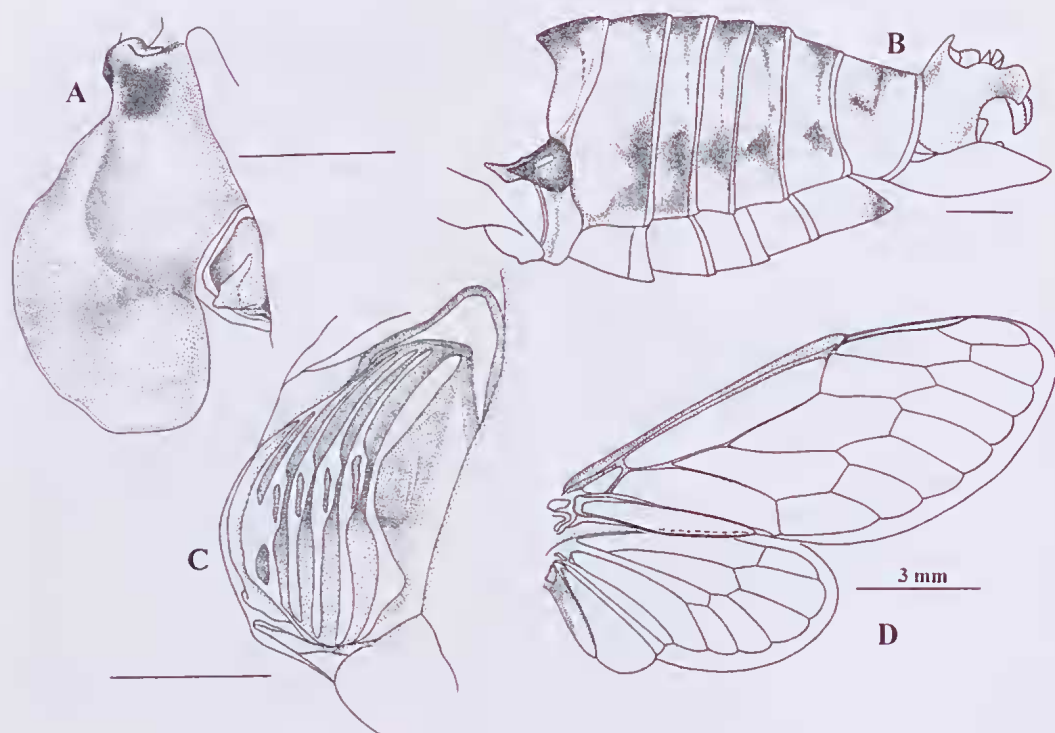


FIG. 6. *Graminitigrina karumbae* sp. nov. Karumba, SE Gulf of Carpentaria. A, left operculum; B, lateral abdomen view; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

8 very reduced and only small dark posterior spot on tergite 9; ventro-lateral dark markings absent on tergites 2-8; tergite 9 with pair of thin irregular pale brown submedial fasciae which merge posterodorsally, and a short, small brown ventro-lateral marking; tergites mostly sandy-brown with conspicuous reddish-brown submedial areas adjacent to posterior margins of each tergite, extending across intersegmental membranes. Sternites uniform sandy-brown. Ovipositor sheath extending ~0.5-1.0mm beyond apex of tergite 9.

MEASUREMENTS. *Bowen specimens:* N = 24♂, 2♀. Ranges and means (in parentheses): BL: ♂ 11.4-13.7 (12.4); ♀ 11.8-12.2 (12.0). FWL: ♂ 11.4-13.6 (12.7); ♀ 12.8 (12.8). HW: ♂ 3.0-3.5 (3.3); ♀ 3.3-3.4 (3.3). PW: ♂ 3.1-3.8 (3.5); ♀ 3.5-3.6 (3.5). AW: ♂ 3.6-4.1 (3.8); ♀ 3.4-3.6 (3.5). FWL/BR: ♂ 2.40-2.65 (2.53); ♀ 2.46-2.51 (2.49).

Croydon, Einasleigh River, and Lynd Highway specimens: N = 19♂, 6♀. BL: ♂ 11.2-13.2 (12.1); ♀ 10.7-13.3 (11.6). FWL: ♂ 11.8-14.0 (12.8); ♀ 12.0-14.3 (13.1). HW: ♂ 3.0-3.4 (3.1); ♀ 2.8-3.6 (3.2). PW: ♂ 2.9-3.6 (3.3); ♀ 3.0-3.8 (3.4). AW: ♂ 3.5-4.0 (3.8);

♀ 3.2-3.9 (3.5). FWL/BR: ♂ 2.43-2.66 (2.53); ♀ 2.46-2.58 (2.50).

Slaty Creek, Cloncurry specimens: N = 11♂, 13♀. BL: ♂ 14.0-14.7 (14.4); ♀ 12.8-14.5 (13.3). FWL: ♂ 13.5-16.2 (14.8); ♀ 13.0-15.7 (14.6). HW: ♂ 3.7-4.0 (3.8); ♀ 3.4-4.0 (3.8). PW: ♂ 3.4-3.7 (3.6); ♀ 3.1-3.7 (3.5). AW: ♂ 4.7-4.9 (4.8); ♀ 3.5-4.3 (4.1). FWL/BR: ♂ 2.44-2.64 (2.51); ♀ 2.44-2.50 (2.48).

DISTRIBUTION, HABITAT AND BEHAVIOUR. (Fig. 5). Known from seven localities, all in northern Queensland; Flagstaff Hill (Bowen); Croydon; Einasleigh River (~35km west of Mt Surprise); 40 and 49km SSW of Lynd-Mt Surprise road junction; 12km SE of the Lynd Road junction (39.5km NW of Greenvale) and Slaty Creek, SW of Cloncurry. The two most distant localities are separated by a linear distance of approximately 830km. Adults occurred in grassland with associated shrubs or low trees. In four localities, the substrate comprised siliceous metamorphic rocks and/or granites, or alluvium derived from these sources, the soils being shallow and poorly developed. The two localities 40 and 49km south of The Lynd-Mt Surprise road

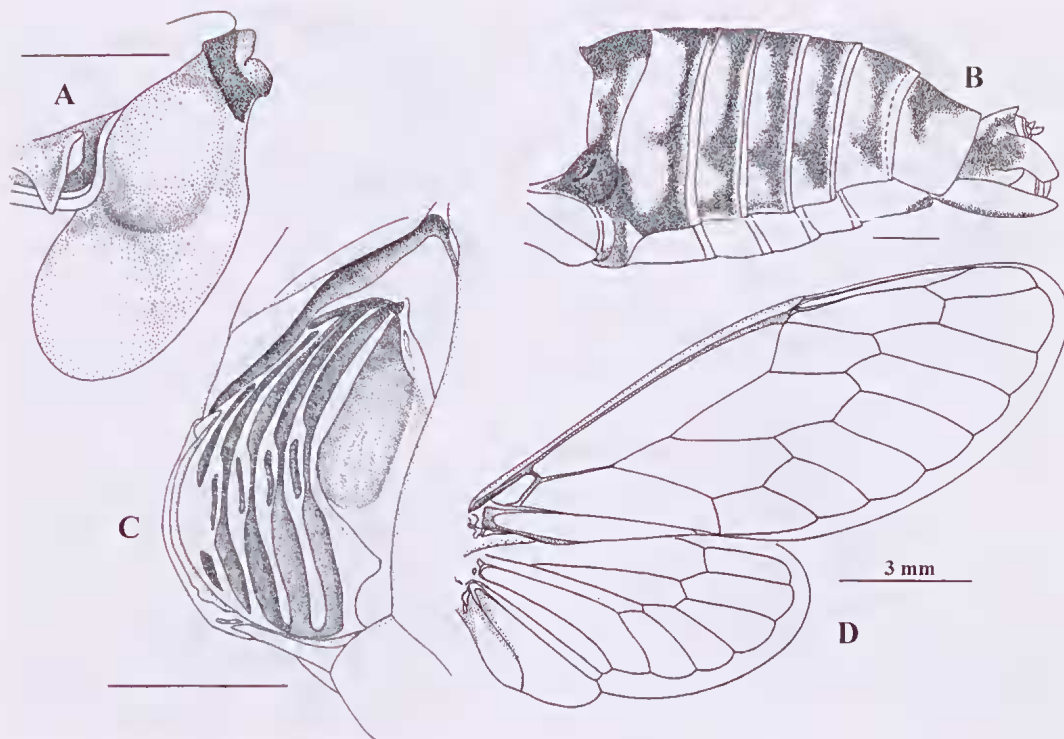


FIG. 7. *Graminitigrina karumbae* sp. nov. Heathlands, northern Cape York Peninsular. A, right operculum; B, lateral abdomen view; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

junction lie on late Tertiary-Quaternary basalts, although south of the main basalt plateau, where the basalt sequences are topographically lower and approaching their outcrop limits. These cicadas have not been found on the main basalt plateau. They are elusive insects, very wary and fast flying when in singing mode, otherwise hiding cryptically in dense grass. The singing behaviour is described below in the song descriptions. Available records are for January-February.

ETYMOLOGY. From the type locality at Bowen, northeastern Queensland.

***Graminitigrina karumbae* sp. nov.**
(Figs 5-8, 25-28, Plate 1F-H, Table 3)

TYPES. HOLOTYPE: ♂, QMT133333, 2km E. Karumba Pt. Village, Karumba, N.W.Q. AE 28 Jan 2002. 17°27.25'S 140°50.63'E, Photog. Spm PS1047 (QM).

PARATYPES. NORTH QUEENSLAND: 3♂, 4♀, 2km E. Karumba Pt. Village, Karumba, N.W.Q., Grass, AE, 28.i.2002, 17°27.25'S 140°50.63'E; 1♂, same data, Recorded Spec. 1; 1♂, same data, Recorded Spec. 2; 1♂, same data, Recorded Spec. 3; 1♂, same,

Recorded Spec. 4; 1♂, 2km E. Karumba Point, N.Q., Grass, AE, 11.i.2003, 17°27.27'S 140°50.76'E, Recorded; 1♂, 2km E. Karumba Point, N.Q., Grass, AE, 12.i.2003, 17°27.27'S 140°50.76'E; 1♂, 1♀, 2km E. Karumba Point, N.Q., Grass, AE, 13.i.2003, 17°27.27'S 140°50.76'E; 1♂, 10.7km E. Heathlands, H.S. (Stn.), Cape York Peninsula, N.Q., 24.i.1992, Heath, AE, 11°45.22'S 142°39.54'; 2♂, same data, 25.i.1992 (AE). 1♂, 1♀, 2km E. Karumba Pt. Village, Karumba, N.W.Q., Grass, AE, 28.i.2002, 17°27.25'S 140°50.63'E (ANIC). 1♂, 2km E. Karumba Point, N.Q., Grass, AE, 11.i.2003, 17°27.27'S 140°50.76'E (BMNH). 1♂, Delta Downs Sn., E of Karumba, N.Q., on grass, 16.xii.1987, MSM and BJM (MSM).

DESCRIPTION. (Male). (A). *Karumba specimens* (Figs 6, 8A-B, Pl. 1G). *Head.* Supra-antennal plate, vertex, mandibular plate and genae black, covered by short golden and longer silver pubescence; small pale sandy-brown patches adjoining antennal pedicels; small pale sandy-brown triangular patch between ocelli extending to posterior margin of supra-antennal plate. Ocelli pink. Compound eyes dark brown. Postclypeus with pale sandy-brown margin and black transverse ridges; midline pale brown dorsally, grading to

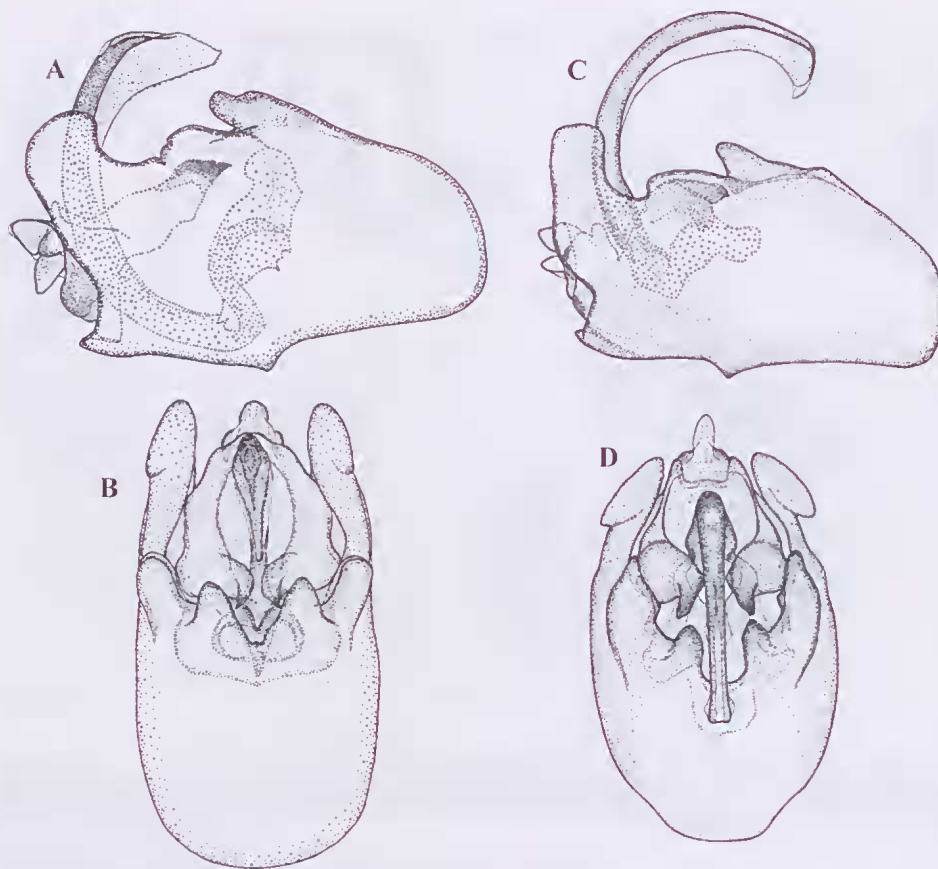


FIG. 8. *Graminitigrina karumbae* sp. nov. Pygofer and male genitalia, Lateral (top) and ventral views (bottom). Specimens from Karumba (A, B) and Heathlands (C, D). Length of pygofers, 2.75 and 2.3mm, respectively.

deep brown ventrally. Anteclypeus deep brown to black; rostrum brown grading to black apically. Antennae black, with brown pedicels.

Thorax. Pronotum mostly black with short, golden pubescence, anterior margin pale sandy-brown; pale sandy-brown central fascia extending from anterior pronotal margin to pronotal collar against which fascia flares out; pronotal collar pale sandy-brown, grading to black and markedly ampliate at lateral angles. Mesonotum with short black submedian sigillae completely fused medially, extending posteriorly as narrow black fascia, widening towards cruciform elevation, filling most of area between its anterior arms. Lateral sigillae black, posterior ends rounded and lying close to anterior arms of cruciform elevation; two small black patches between anterior and posterior arms of cruciform elevation; rest

of mesonotum pale sandy-brown. Short sparse golden pubescence over most of mesonotum.

Wings. Venation pale sandy-brown, dark brown along anterior margin of costal vein. Hind wing with white, opaque plaga extending along margins of veins 3A and 2A.

Legs. Fore coxae mostly brown, with narrow, paler fasciae anteriorly; mid and hind coxae brown along lateral margins, otherwise pale sandy-brown. Trochanters and outer faces of fore femora pale sandy-brown, dark brown on posterior faces. Mid and hind femora pale sandy-brown with some darker brown longitudinal fasciae, less marked on hind femora. Tibiae and tarsi pale sandy-brown, elaws slightly darker.

Opercula. Somewhat elongated, distal and medial margins broadly rounded, pale sandy coloured

except for small pale brown basal patches near crest in distolateral corners; meracantha spikes relatively short; medial area weakly slanted inwards towards abdominal midline; in lateral view, distal margin of opercula extending to anterior margin of sternite II; in ventral view, medial opercula margins markedly overlap distal margins of tympanal cavities.

Timbals. Long rib 4 fused dorsally to basal spur and ventrally to ribs 1-3; rib 5 close to, but not in contact with anterodorsal timbal margin, not extending more than half way along adjacent short rib; small, isolated long rib fragment located ventrally well below long rib 5; four clearly defined short ribs.

Abdomen. Maximum width across tergite 3 similar to that across auditory capsules; in dorsal view, abdomen narrowing gently to tergite 7, then tapering more strongly to pygofer. Tergites mostly sandy-brown; tergites 2-7 each with median, brown to black, roughly triangular-shaped patch that is widest posteriorly; patch on tergite 2 confluent with central dark patch on T1 that fills area between timbals; central patches becoming paler brown towards tergite 7; tergite

8 with two dark, irregular patches joined by a thin, transverse dark line. Tergites 2-6 laterally with smaller, roughly triangular-shaped brown patches that are widest posteriorly. Sternites sandy-brown, VII and VIII slightly darker.

Genitalia. (Fig. 8) Pygofer sandy-brown with two somewhat irregular, thin, submedian, brown fasciae tending to converge posteriorly. Upper pygofer lobes strongly decurved; apices broadly rounded; aedeagus with long theca recurved into broad U-shape; thin, lightly sclerotised, finely serrated, wafer-like process along inner curve of theca, widening and extending beyond tip of theca apically; theca with distinct ventral split towards, and extending to apex; pseudoparameres absent.

(B). *Heathlands specimens.* (Figs 7, 8, Pl. 1F) Head and thorax very similar to Karumba specimens but pale central fascia on pronotum not quite extending to pronotal collar, pale pronotal collar wider submedially. Principally differ from Karumba specimens in increased extent and intensity of black colouration on abdomen. Dorsal black markings wider than Karumba specimens, extending from between timbals on tergite 1 to pygofer, together

TABLE 3. *Graminitigrina karumbae* - summary of calling song parameters. Data compiled from separate container recordings from three insects (Karumba Point) and one insect (Heathlands).

Location	Karumba Point	Heathlands, Cape York
a. Chirp phrases (=short echemes ± associated clicks)		
Repetition rates (s ⁻¹)	0.51(0.66-0.33) ⁽¹⁾	0.47(0.65-0.33)
No. of initial clicks per chirp phrase	6.9(2-13) ⁽¹⁾	4.6(3-9)
Total chirp lengths (s)	1.05(0.85-1.22) ⁽¹⁾	1.27(1.06-1.45)
b. Single click phases (= single discrete macrosyllables)		
Macrosyllable lengths (ms); excluding tails	13.4(11.5-14.2) ⁽¹⁾	20.6(18.0-21.7)
Macrosyllable lengths (ms); including tails	16.8(15.0-17.7) ⁽¹⁾	24.7(22.7-26.5)
Syllable lengths (ms); excluding tails	2.6(2.3-2.9) ⁽¹⁾	3.4(3.2-3.9)
Syllable lengths (ms); including tails	7.6(6.6-9.0) ⁽¹⁾	12.5(11.5-13.0)
Hemisyllable lengths (ms)	0.73(0.54-0.88) ⁽¹⁾	0.76(0.44-1.02)
Click repetition rates (s ⁻¹)	2 - 68	3 - >100
Doublet intervals; main sequence prior to echeme (ms)	9.0(0.83-10.2) ⁽¹⁾	12.5(11.4-13.3)
Doublet intervals; final 3 to 6 clicks adjacent to echeme (ms)	4.5-7.7	4.5-7.4 (final 3)
Secondary peak widths (ms)	2.3(2.0-2.8) ⁽¹⁾	2.4(2.2-2.5)
c. Short echeme phrases		
Macrosyllable lengths (ms)	11.5(10.9-13.3) ⁽¹⁾	15.2(14.3-15.6)
Syllable lengths (ms)	1.5(1.3-2.0) ⁽¹⁾	2.4(1.3-2.9)
Syllables per macrosyllable	7	7
Hemisyllable lengths (ms)	0.62(0.41-0.92) ⁽¹⁾	0.50(0.38-0.70)
d. Dominant frequency (kHz)		
	8.88 (8.50-9.12) ⁽¹⁾	7.85

⁽¹⁾Values represent mean and (ranges).

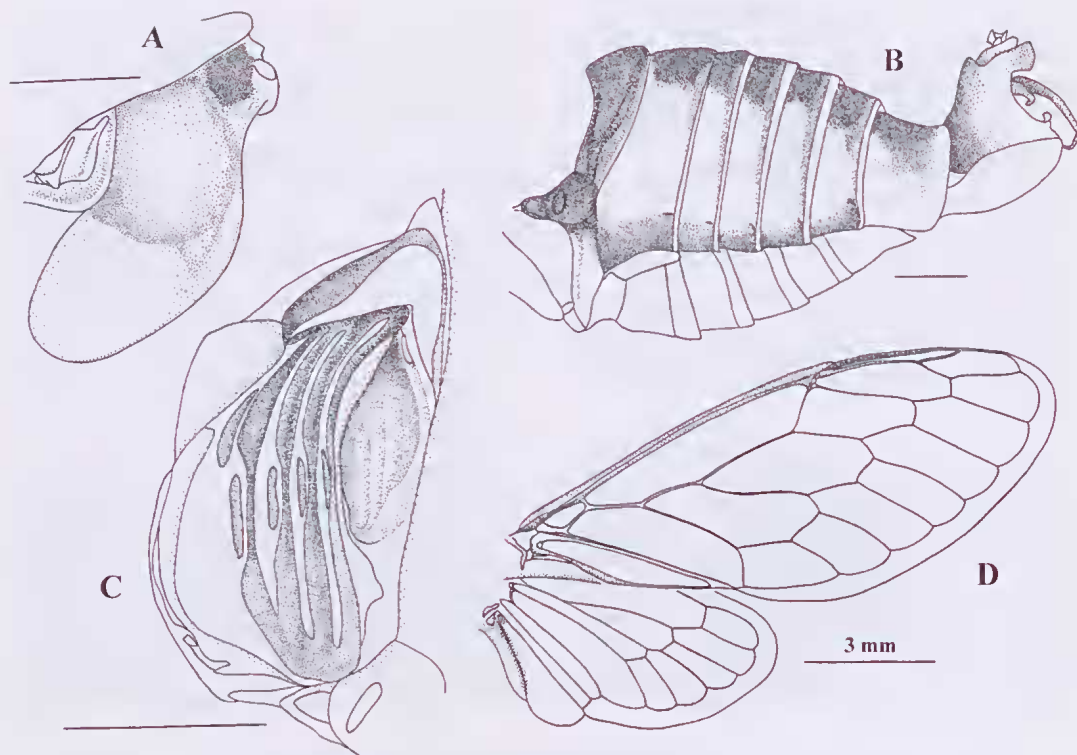


FIG. 9. *Graminitigrina bolloni* sp. nov. A, right opereulum; B, lateral abdomen view; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

creating appearance of dark, dorsal fascia. Tergite 2 with narrow irregular transverse band extending laterally to, and enclosing auditory capsule; tergites 3-7 with posterior, narrow, dark transverse bands that are conspicuously widened ventrally; bands on tergites 3 and 4 extending to ventral margins of tergites in lateral view; rest of tergites sandy-orange-brown, more intense than in Karumba specimens. Sternite II exhibits a narrow brown zone, parallel to submedian margin; sternites III-VII sandy/orange-brown, tergite VII dark posteriorly; sternite VIII sandy-orange-brown laterally, dark brown medially. Legs similar to Karumba specimens in general patterning but dark areas more extensive and darker. Timbal structure very similar, but long rib 4 not fused either dorsally to basal spur, or ventrally to ribs 1-3. Some minor differences in shape of pygofer, the lower lobe, and detailed shape of wafer-like process extending along inner margin of theca.

FEMALE. (Pl. 1H) *Karumba locality*. Similar to male but slightly paler overall. Supra-antennal plate and vertex black to deep brown, with

pale sandy-brown area along anterior margin extending from fronto-ocellar suture almost to compound eyes; pale fascia extending from median ocellus to posterior margin of supra-antennal plate. Postclypeus as in male, but deep brown rather than black; anteclypeus brown to sandy-brown; rostrum sandy-brown grading to black apically. Pronotum mostly black to dark brown; central fascia pale sandy-brown with thin brown edges; pronotal collar as in male. Mesonotum as in male with submedian and lateral sigillae slightly smaller. Wings and legs similar to male. Abdominal markings similar in form and shape to male, but generally slightly paler; dorsal brown markings on tergites 2-7; tergites 8 and 9 predominantly pale sandy-brown. Sternites uniformly pale sandy-brown. Ovipositor sheath extending 0.5-1mm beyond apex of tergite 9.

MEASUREMENTS. N = 15♂, 5♀. Ranges and means (in parentheses). *BL*: ♂ 12.2-13.5 (13.0); ♀ 11.0-11.2 (11.1). *FWL*: ♂ 12.2-14.0 (13.0); ♀ 12.6-13.0 (12.8). *HW*: ♂ 3.0-3.4 (3.2); ♀ 3.0-3.2 (3.1). *PW*: ♂ 3.3-3.9 (3.5); ♀ 3.3-3.5 (3.4). *AW*: ♂ 3.8-4.1 (3.9); ♀ 3.5-

3.6 (3.5). FWL/BR: ♂ 2.42-2.62 (2.54); ♀ 2.52-2.68 (2.60).

DISTRIBUTION, HABITAT AND BEHAVIOUR. (Fig. 5). Known from three localities in northern Queensland; Karumba Point (southeastern Gulf of Carpentaria), Delta Downs NE of Karumba and Heathlands, northern Cape York Peninsula, the two most distant localities separated by a linear distance of 655km. At Karumba Point, adults occur in grassland on low plains, formed of coastal alluvial deposits, seasonally inundated by freshwater. At Heathlands, the cicada occur in dense low heathland, dominated by *Sinoga lysicephala*, lying on weathered quartzose sandstones and siltstones of Mid Jurassic-Early Cretaceous age (Helby Beds). The adults of this species are highly elusive, being very wary and fast flying when disturbed, often flying up to 10m, but sitting cryptically when not singing. The singing behaviour is described below. Records are available only for December and January, following monsoonal rains.

ETYMOLOGY. From the type locality at Karumba Point, southeastern Gulf of Carpentaria, north Queensland.

***Graminitigrina bolloni* sp. nov.**

(Figs 5, 9, 10, 29 - 32, Plate 2A-B, Table 4)

MATERIAL. HOLOTYPE: ♂, QMT133334, 0.7km E. Bollon, S.Q. Grass, 12 Dec. 2001, AE 28°01.85'S 147°29.39'E; Photog. Spm PS1046. **PARATYPES:** SOUTHERN QUEENSLAND: 1♂, 0.7km E. Bollon, Grass, 10.xii, 2001, AE, 28°01.85'S 147°29.39'E; 1♂, same data, Recorded Spec. 1; 1♂, same data, Recorded Spec. 2; 1♂, same data, Recorded Spec. 3; 1♂, 1♀, same data but 12.xii, 2001; 4♂, 1♀, 1 exuvia, 1km S.E Bollon, S.Q., 20.xii.2004, Grass (in mulga), AE, 28°02.27'S 147°29.49'E; 1♂, same data, Recorded 1; 1♂, same data, Recorded 2; (AE). 1♂, QLD 27°32'01"S 148°50'25"E, 65km NNE. St George, 9.i.2005. Roadside. L.W. Popple, R. MaeSloy, 370-0001*; 7♂, 10km E. of Jericho, 11.i.2007, Grassland. L. Popple, J. Herewood, 23°36'37"S 146°14'34"E, 371-0007* (LWP). 1♂, 1♀, 1km S.E Bollon, S.Q., 20.xii.2004, Grass (in mulga). AE, 28°02.27'S 147°29.49'E; (ANIC). 1♂, same data (BMNH). 1♂, same data (MSM).

*Species and specimen numbers in private collection of LWP.

DESCRIPTION. (Male). Figs 9, 10, Pl 2A. **Head.** Supra-antennal plate, vertex, mandibular plate and genae shiny black, covered by short golden pubescence (supra-antennal plate only), and longer silvery pubescence; small sandy-brown patches extending along anterior margin of supra-antennal plate from pedicels of antennae to lateral margin of

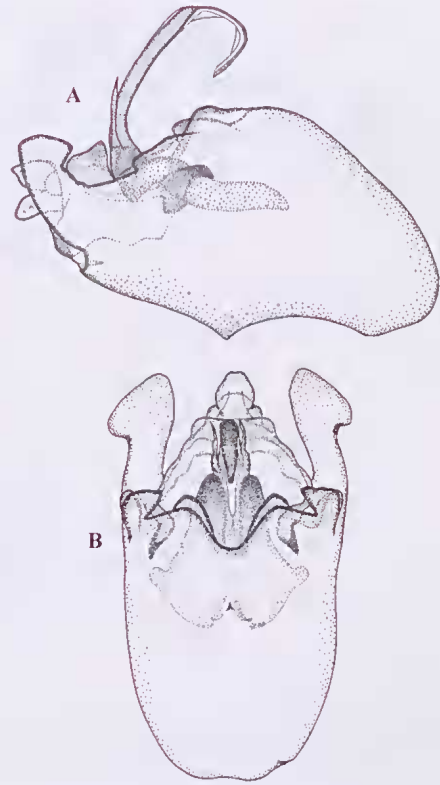


FIG. 10. *Graminitigrina bolloni* sp. nov. Pygofer and male genitalia, lateral (A) and ventral views (B). Specimen from Bollon. Length of pygofer, 2.6mm.

postclypeus; short triangular sandy-brown fascia extending from median ocellus, and widening towards and reaching posterior margin of vertex. Ocelli pink to rose-red. Compound eyes deep brown. Dorsal surface of postclypeus shiny black with short golden pubescence dorsally; anterior surface shiny black with narrow pale chestnut brown margin which does not extend along transverse grooves; small sandy-brown dorsal spot on midline. Anteclypeus shiny black; rostrum pale brown, grading to black apically. Antennae mostly black with pale brown pedicels.

Thorax. Pronotum shiny black, ventro-lateral margins sandy-brown; sandy-brown central fascia extending from anterior margin towards, but not quite reaching posterior margin; pronotal collar pale chestnut brown with a broader sandy-brown margin submedially; lateral angles of pronotal collar markedly ampliate and pale chestnut brown; pronotum covered with short golden pubescence. Mesonotum with submedian sigillae black, short, completely fused medially; very narrow black

TABLE 4. *Graminitigrina bolloni* - summary of calling song parameters. Data compiled from separate recordings from four insects (Bollon; container recordings) and two insects (Jericho; field recordings).

	Bollon ('normal' song)	Jericho
Chirps (short echemes + associated clicks)		
1. Chirp repetition rates (s^{-1})		
(a) Echeme + 2 clicks	2.2(3.3-1.9)	-
(b) Echeme + 3 clicks	2.4(2.3-2.9)	4.2(3.7-4.5)
(c) Echeme + 4 clicks	1.9(2.1-1.8)	4.4(3.7-5.0)
2. Short echeme lengths (ms)	64(54-90)	46(39-60)
3. Inter-click intervals and repetition rates (ms)		
(a) Excluding final 3 clicks (1 to 3) (only for ≥ 4 click sequences):	157(124-191) [6.4Hz(8.1-5.2Hz)]	39(34-42) [26Hz(29-24Hz)]
(b) Between clicks 3 to 2	104(86-113) [9.6Hz(11.6-8.9Hz)]	41(36-47) [24Hz(28-21Hz)]
(c) Between clicks 2 to 1	53(43-67) [19Hz(23-15Hz)]	29(27-32) [34Hz(37-31Hz)]
(d) Between click 1 and echeme	29(23-38) [34Hz(43-26Hz)]	22(18-24) [45Hz(23-42Hz)]
4. Individual clicks (= single macrosyllables)		
A. Triplet click sequences (including initial syllable of each click)		
(i) Total click length (excluding final tail)(ms) [=Macrosyllable]	21.7(19.9-23.7)	14.0(13.0)-16.2)
(a) Inter-syllable intervals (ms) - see Fig. 31c		
(i) Syllables 1 to 2 intervals	8.0(6.8-9.1)	4.2(3.9-5.0)
(ii) Syllables 2 to 3 intervals	7.8(5.3-8.7)	9.4(9.0-9.7)
B. Quadruplet click sequences (including initial syllable of each click)		
(i) Total click length (excluding final tail)(ms) [=Macrosyllable]	30.6(26.1-33.0)	13.3(12.5-14.1)
(b) Inter-syllable intervals (ms) - see Fig. 31b		
(i) Syllables 1 to 2	8.4(7.3-9.2)	3.7(3.5-4.3)
(ii) Syllables 2 to 3	9.3(8.1-9.5)	5.5(5.1-7.0)
(iii) Syllables 3 to 4	10.0(9.9-10.2)	3.2(2.0-4.2)
C. Syllable lengths (ms) - all data		
(i) Syllable 1	4.4(3.6-5.3)	1.2(0.8-1.9)
(ii) Syllable 2	6.0(4.6-7.9)	2.4(2.0-3.3)
(iii) Syllable 3	5.6(4.4-7.9)	2.0(1.9-2.1)
(iv) Syllable 4	4.4(4.0-4.8)	1.6(1.3-2.3)
D. Occurrence of triplet/quadruplet click sequences		
(i) Triplet sequences	>3 clicks per echeme	-
(ii) Quadruplet sequences	≤ 3 clicks per echeme	-
E. Hemisyllable lengths (ms) - 4 per syllable		
(i) Syllable 1	0.91(0.53-1.2)	-
(ii) Syllable 2	1.2(0.56-1.7)	-
(iii) Syllable 3	0.89(0.40-1.13)	-
(iv) Syllable 4	1.1(0.81-1.8)	-
5. Echemes (multiple coalesced macrosyllables)		
A. Macrosyllables - lengths (ms)	16.0(12.0-20.9)	9.0(8.6-13.7)
B. Syllable lengths (ms)	3.8(2.4-6.0)	2.5(1.8-5.1)
6. Dominant frequency (kHz)	9.63 (9.30-10.22)	9.28 (9.03-9.53)

Figures are means and (ranges); figures in square brackets are equivalent frequencies (Hz).

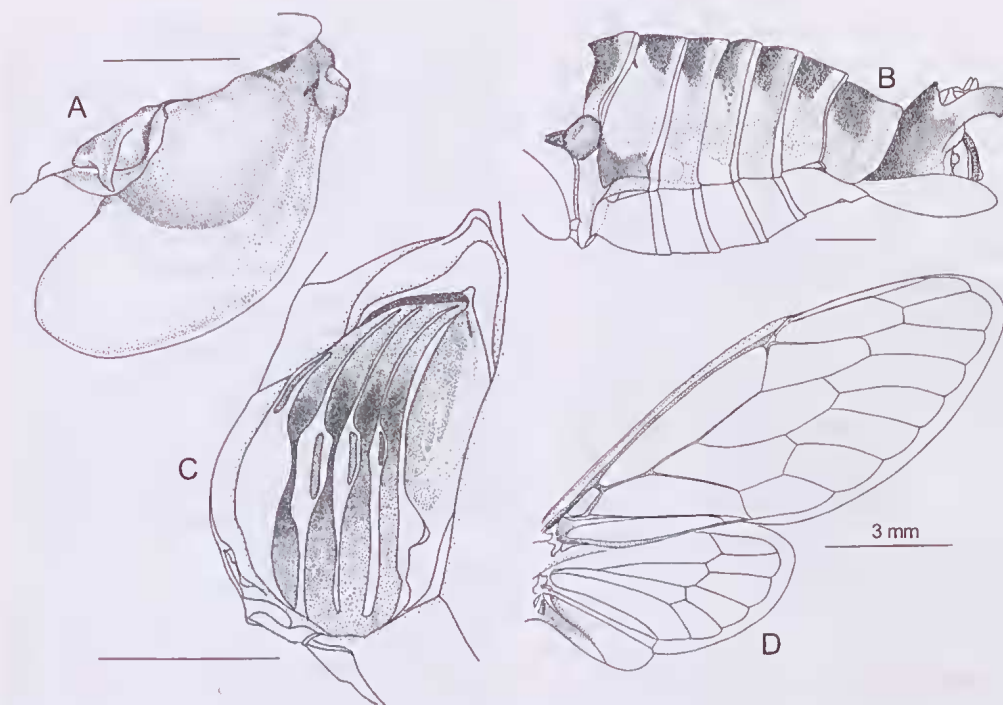


FIG. 11. *Graminitigrina carnarvonensis* sp. nov. Mt Moffatt Section of Carnarvon National Park. A, right operculum; B, lateral abdomen view; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

fascia extending posteriorly from submedian sigillae, widening abruptly near, and extending between anterior arms of cruciform elevation; lateral sigillae black, roughly triangular, narrowing posteriorly, terminating near apices of anterior arms of cruciform elevation; medial edges of sigillae broken by 'veinlets' of sandy-brown colouration; small, irregular, dark brown patches within areas between anterior and posterior arms and between both posterior arms of cruciform elevation; rest of mesonotum, including wing grooves, sandy-brown; mesonotum with sparse silvery pubescence, longer and more profuse around cruciform elevation.

Wings. Venation pale sandy coloured, becoming brown apically; costal vein very pale sandy-yellow; very narrow sclerotised brown anterior margin to costal vein. Hind wing with white opaque plaga along margins of veins 3A and 2A, and weak brown infuscation centrally within anal cell 3; four to five apical cells.

Legs. Fore coxae sandy-brown with lozenge-shaped dark brown areas covering much of anterior faces, posterior faces with broad short dark

brown fascia; mid and hind coxae similar but with smaller paler brown markings; trochanters and fore femora mostly dark brown on anterior faces, sandy-brown with two broad longitudinal fasciae on posterior faces; mid femora sandy-brown with a pair of brown fasciae on posterior faces; hind femora similar, with fasciae thinner and paler; fore tibiae and tarsi medium to dark brown; mid and hind tibiae and tarsi sandy-brown; claws sandy-brown with dark brown apices.

Opercula. Relatively elongated and narrowly rounded along distal-medial margins; distal area gently curved towards abdominal midline; sandy coloured except for small dark brown patches near basal crests; basal half of operculum convex, broad and dome-like; spikes on meracantha short, broad, not overlapping opercula plates; in lateral view, operculum just overlapping anterior margin of sternite II submedially.

Timbals. Long ribs 1-4 fused ventrally, and dorsally to basal spur; rib 5 short, not reaching anteriormost short rib; 4 clearly defined short ribs; dome on timbal plate with distinct ridges, approximately parallel to long ribs.

Abdomen. Maximum width across tergite 3 slightly greater than across auditory capsules; in dorsal view, abdomen evenly tapering from tergites 3-8. Tergite 2 shiny black except for narrow, pale sandy-brown posterior margin, black colouration extending across, and just beyond ventral margins of auditory capsules, and anteriorly to between timbals on tergite 1; tergites 3-8 with well defined, shiny black, dorsal patches, more or less subequal in width on tergites 3-7; within each tergite, patches taper posteriorly, those on tergites 4-7 not extending on to, or across intersegmental membranes; dark dorsal patch on tergite 9 larger, extending to about lateral margin of tergite in dorsal view; tergites 3-7 with black to dark brown patches along ventrolateral margins, these becoming smaller and paler posteriorly; remaining colouration of tergites pale sandy-brown to dark sandy-brown, progressively darkening distally; posterior margins of tergites 3-6 with distinct reddish-chestnut brown zones submedially, these not extending across intersegmental membranes; dorsally, these reddish-brown zones lie between black dorsal patches and intersegmental membranes. Sternite II pale sandy-brown, black medially; sternites III-VI sandy-brown, VII-VIII slightly darker.

Genitalia. (Fig. 10) Pygofer dark brown dorsally and basally and on upper lobes, otherwise sandy-brown. Upper pygofer lobes relatively sharply decurved; apices with acutely rounded corners, distal margin straight to gently convex; aedeagus with long, strongly curved theca, its apex recurved 180° and hook-like; pseudoparameres distinct, much shorter than theca, originating near thecal base.

FEMALE. (Pl. 2B) Very similar in overall colouration to male, but with slightly more extensive pale areas. Differing from male as follows: larger sandy-brown patches around pedicels of antennae and along margins of genae. Postclypeus with broader sandy-brown margin and enlarged sandy-brown spot dorsally on mid-line of frons. Antennae dark brown, pedicels sandy-brown. Mesonotum similar to male, except median, narrow, black fascia extending from nearly coalesced black submedian sigillae only extending midway along mesonotum, not reaching anterior arms of cruciform elevation; two small black spots (scutal depressions) distinct, not enveloped within dark colouration; central area of cruciform elevation reddish. Wings as in male, one specimen examined with only 3 hind wing apical cells. Legs; fore coxae mostly sandy-

brown with faint, pale brown, broad fascia; mid and hind coxae with reduced brown markings; femora and trochanters with narrower and paler brown fasciae; tibiae and tarsi sandy-brown, with claws darker brown on apices. Abdomen: tergite 2 black dorsally and submedially along anterior margin, dorsal black marking reducing in width towards posterior margin and not extending over intersegmental membrane; tergite 2 otherwise sandy-brown with narrow chestnut-brown submedian area adjacent to posterior margin; tergites 3-8 with dorsal, well-defined, black patches that decrease in width posteriorly within each tergite; patches progressively decreasing in size from tergites 3-8; tergites 3-8 each with narrow but distinct reddish to chestnut-brown zone dorsally and submedially along posterior margins; tergites otherwise pale to medium sandy-brown, darkening posteriorly towards tergite 8; tergite 9 sandy-brown with a pair of brown, submedian, longitudinal fasciae, that terminate approximately three-quarters along length of tergite; each fascia slightly expanded and rounded posteriorly; less conspicuous, paler brown dorsal fascia of tergite 9, narrowing posteriorly and shorter than paramedial fasciae; sternites pale sandy-brown. Ovipositor sheath extending 0.8-1.1 mm beyond apex of tergite 9.

MEASUREMENTS. N = 16♂, 2♀. Ranges and means (in parentheses). *BL*: ♂ 10.7-12.3 (11.6); ♀ 11.2-12.7 (12.0). *FWL*: ♂ 12.0-12.5 (12.3); ♀ 12.4-12.7 (12.6). *HW*: ♂ 3.0-3.3 (3.1); ♀ 3.2 (3.2). *PW*: ♂ 3.1-3.6 (3.4); ♀ 3.5-3.6 (3.5). *AW*: ♂ 3.4-3.9 (3.7); ♀ 3.3-3.6 (3.5). *FWL/BR*: ♂ 2.34-2.58 (2.46); ♀ 2.44-2.48 (2.45).

DISTRIBUTION, HABITAT AND BEHAVIOUR. (Fig. 5) Known from three localities in southern to central inland Queensland; Bollon, 65 km NNE of St George and 10 km E of Jericho, a distribution extending over a linear distance of approximately 505 km. At each location, the cicada occurs only in grassland: at Bollon within open mulga (*Acacia aneura*) woodland; north of St George within poplar box (*Eucalyptus populnea*)-*Eremophila mitchellii*-*Calliiris*-sparse mulga open woodland; at Jericho, within mixed eucalypt-acacia (c.g. *E. melanophloia*, *E. crebra*, *E. cambageana*, *A. melvillei*, *A. shirleyi*) open woodland with *Kunzia* sp. At Bollon, the bedrocks are quartz sands, silts and gravels, giving rise to sandy or loamy soils. The locality north of St George is also dominated by lithic sandstones, siltstones and minor mudstones, and alluvium derived from these, with soils that are gravelly and loamy red earths. The Jericho locality

is likewise characterised by quartz sandstones and siltstones and their derived gravelly soils.

The adults of this species are highly elusive and fast flying insects while singing. In between bouts of song, they rest very cryptically, low on dense grass stems. The singing behaviour is described in more detail below. The insect emerges after heavy summer rains. Available records are for December to January.

ETYMOLOGY. From the type locality Bollon, southern Queensland.

***Graminitigrina carnarvonensis* sp. nov.**

(Figs 5, 11, 12, 33-35, Plate 2C–D, Table 5)

MATERIAL. HOLOTYPE: ♂, QMT133335, 24°59'28"S 147°53'48"E Mt Moffatt NP, SCQ, Marlong Arch. 820m, 19 Nov 1995, C.J. Burwell, Photog. Spm PS1044.

PARATYPES: SOUTH QUEENSLAND: 1♂, 4.3km NNE., Mt Moffatt NP entrance gate, grass, 13.xii.2006, AE, 25°05.09'S 147°52.42'E; 1♂, 6.9km SW., triple Jct of tracks Inform. Ctr-Marlong-Top Shelter, Mt Moffatt., grass, 14.xii.2006, AE, 24°58.52'S 147°55.92'E; 4♂, 3.7km NE. Marlong Arch, along rd, Mt Moffatt NP, grass, AE, 15.xii.2006, 24°58.44'S 147°56.17'E; 1♂, same data, Field recorded, open net; 1♂, 4.3km NNE., Park Entrance, Mt Moffatt N.P., grass, AE, 16.xii.2006, 25°05.06'S 147°52.49'E (AE). 3♂, 25°01'S 147°47'E, Mt Moffatt NP, Park Headquarters, 17.xi.1995, 740m CJB; 1♂, 25°04'39"S 148°00'30"E Mt Moffatt NP, Base of the Tombs, 17.xi.1995, 700 m, S. Gaimari; 1♀ 25°01'S 147°47'E, Mt Moffatt Nat. Pk. Park Headquarters, 18.xi.1995, 740m CJB; 1♂, 25°05'S 147°53'E, Base of the Tombs, Mt Moffatt Nat. Pk., 28.xi-3.xii.1997, Evans, Skevington, Lambkin (QM). 1♂, Queensland Camarvon NP, Mt Moffatt, 25° 06'00"S 147°51'15"E, C. Eddie, 29.xi.1995, 371-0006*; 3♂, QLD 24°57'25"S 147°54'19"E, Mt Moffatt NP, North-west Rd., 15.i.2005, L.W. Popple, 371-0005, 4, 3*; 2♂, QLD, 25°05'21"S 147°52'23"E, The Tombs, Mt Moffatt NP, 14.i.2005, L.W. Popple, 371-0002* (LWP). 1♂, Qld: Camarvon NP, Mount Moffatt Section, Malaise, 25°03'15"S 147°53'12"E, 26.xi.1997, J. Skevington, C. Lambkin; 1♂, same data, 1-2.xii.1997; 1♂, QLD: Camarvon NP; Mt Moffatt Section, Mt Moffatt Rd, Sandy Creek, 25°04'01"S 148°00'50"E, 2.xii.1997, J. Skevington, C. Lambkin, S. Evans, malaise (JM). 1♂, 25°04'39"S 148°00'30"E, Mt Moffatt Nat. Pk, 3km SE Park Headquarters, 20.xi.1995, 740m. CJB; (ANIC). 1♂, 25°02'18"S 147°58'30"E, Mt Moffatt NP, 3km SE Park Headquarters, 19.xi.1995, 740m, Irwin, Gaimari, Yeates, Burwell, Malaise (BMNH). 1♂, Chesterton Range N. P., Qld, 10.xii.1995, spinifex, eucalypt open woodland, Colin Dollery (MSM).

*Species and specimen numbers in private collection of LWP.

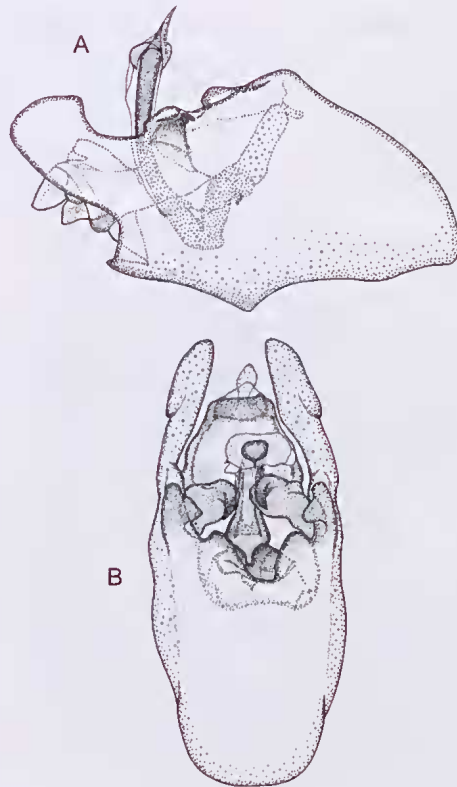


FIG. 12. *Graminitigrina carnarvonensis* sp. nov. Pygofer and male genitalia, Lateral (A) and ventral views (B). Specimen from Mt Moffatt. Length of pygofer, 2.9mm.

DESCRIPTION. (Male). Figs 11, 12, Pl. 2C. *Head.* Supra-antennal plate and vertex shiny black, with narrow anterior sandy-brown rim extending around pedicels of antennae, but not to margins of compound eyes; short, triangular, pale sandy-brown fascia extending from near median ocellus, widening towards, and reaching posterior margin of vertex; sparse dorsal short golden pubescence; mandibular plate shiny black, genae black dorsally, pale reddish brown along lateral to ventral margins; long yellowish pubescence on mandibular plate and genae. Ocelli rose-red. Compound eyes chestnut-brown. Postclypeus shiny black, covered with short golden pubescence on dorsal surface; anterior surface shiny black with pale chestnut-brown margin which only slightly extends along transverse grooves; small pale sandy-brown spot middorsally. Anteclypeus shiny black; rostrum pale

TABLE 5. *Graminitigrina carnarvonensis* - summary of calling song parameters. Data compiled from separate open net field recordings from three insects (Mt Moffatt).

1. Chirp phrases		
(i) Chirp lengths (ms)		151(120-190) ⁽¹⁾
(ii) Chirp repetition rates (ms)		261(209-366)[3.8Hz(4.8-2.7Hz)] ⁽²⁾
2. Click phases (= diplosyllables)		
(i) <i>Inter-hemisyllable intervals (ms)</i>		
Diplosyllable 1	- initial to second hemisyllable	20.3(17.9-21.7)[49Hz] ⁽³⁾
	- second hemisyllable to following diplosyllable	44.5(32.7-59.8)[22Hz]
Diplosyllable 2	- initial to second hemisyllable	17.8(14.8-20.7)[56Hz]
	- second hemisyllable to following diplosyllable	20.6(15.1-29.6)[49Hz]
Diplosyllable 3	- initial to second hemisyllable	8.3(4.8-10.0)[120Hz]
	- second hemisyllable to following diplosyllable	13.3(11.1-15.8)[75Hz]
Diplosyllable 4	- initial to second hemisyllable	5.2(3.7-5.9)[192Hz]
	- second hemisyllable to following diplosyllable	9.7(8.2-13.6)[103Hz]
Diplosyllable 5	- initial to second hemisyllable	5.0(4.9-5.6)[200Hz]
	- second hemisyllable to following diplosyllable	7.2(5.8-9.9)[139Hz]
Diplosyllable 6	- initial to second hemisyllable	5.0(3.5-5.6)[200Hz]
(ii) <i>Inter-diplosyllable intervals (ms)</i>		
Diplosyllables	1 to 2	64.9(51.9-81.5)[15Hz]
	2 to 3	38.3(31.1-45.2)[26Hz]
	3 to 4	21.6(18.3-25.4)[46Hz]
	4 to 5	13.9(13.4-17.3)[72Hz]
	5 to 6	12.1(10.5-13.4)[83Hz]
(iii) <i>Hemisyllable doublet intervals between peak pairs (ms); S = single initial hemisyllables</i>		
Diplosyllable 1	- initial (dominant) hemisyllable	S
	- second hemisyllable	1.6(0.9-2.0)[625Hz]
Diplosyllable 2	- initial (dominant) hemisyllable	S→1.2
	- second hemisyllable	1.7(1.4-2.0)[588Hz]
Diplosyllable 3	- initial (dominant) hemisyllable	S→2.3
	- second hemisyllable	2.1(1.4-2.7)[476Hz]
Diplosyllable 4	- initial (dominant) hemisyllable	1.4(0.6-2.1)[714Hz]
	- second hemisyllable	1.5(1.0-1.8)[667Hz]
Diplosyllable 5	- initial (dominant) hemisyllable	1.5(0.4-2.1)[667Hz]
	- second hemisyllable	1.4(1.1-2.0)[714Hz]
Diplosyllable 6	- initial (dominant) hemisyllable	1.7(0.9-2.6)[588Hz]
	- second hemisyllable	1.5(0.8-2.0)[667Hz]
(iv) <i>Hemisyllable lengths (ms); S = single initial hemisyllables</i>		
Diplosyllable 1	- initial (dominant) hemisyllable	1.7-1.9; S
	- second hemisyllable	2.2-2.4
Diplosyllable 2	- initial (dominant) hemisyllable	1.7-2.0; S→Doublet
	- second hemisyllable	2.4-3.0
Diplosyllable 3	- initial (dominant) hemisyllable	2.0-2.8; S→Doublet
	- second hemisyllable	2.4-3.0
Diplosyllable 4	- initial (dominant) hemisyllable	2.9-3.3
	- second hemisyllable	2.1-2.3
Diplosyllable 5	- initial (dominant) hemisyllable	2.6-2.8
	- second hemisyllable	2.1-2.2
Diplosyllable 6	- initial (dominant) hemisyllable	2.7-2.8
	- second hemisyllable	2.0-2.2
(v) <i>Small 'pulse disturbances' following initial hemisyllable; intervals between 'disturbance' and initial hemisyllable, and 'disturbance' length (in brackets); (ms)</i>		
Diplosyllable 1	initial hemisyllable to 'disturbance'	2.5-5.6(1.1-1.9)
Diplosyllable 2	initial hemisyllable to first 'disturbance'	3.2-5.4(0.1-1.0)
Diplosyllable 3	initial hemisyllable to 'disturbance'	3.2-5.4(0.9-1.0)
3. Dominant frequency (kHz)		10.11 (9.78-10.60)

(¹)Values represent mean and (ranges). (²)Values represent mean, (ranges) and [equivalent mean and ranges of frequency]. (³)Equivalent mean frequency of mean inter-diplosyllable intervals.

sandy-brown, grading to black apically. Antennae deep brown with pale sandy-brown pedicels.

Thorax. Pronotum shiny black, ventro-lateral and narrow anterior margins pale sandy-brown;

pale sandy-brown central fascia extending from anterior margin to, and splaying out along anterior margin of pronotal collar; pronotal collar black with narrow, pale sandy to chestnut-brown posterior margin; lateral angles of pronotal collar

markedly ampliate; pronotum with sparse, short, silver-yellow pubescence. Mesonotum mostly black due to complete fusion of submedial sigillae which extend posteriorly, with initial slight medial narrowing and then widening, to completely cover area between anterior arms of cruciform elevation; broad black lateral sigillae extending from anterior mesonotal margin, with some narrowing, to just beyond apices of anterior arms of cruciform elevation; lateral mesonotal margins, very narrow zones between lateral and submedial sigillae, wing grooves, and cruciform elevation pale sandy-brown; small darker areas between anterior and posterior arms of cruciform elevation, and within posterior area of wing grooves.

Wings. Fore wing venation pale sandy-brown, becoming brown apically; costal vein pale sandy to medium brown in mid part of vein; very narrow sclerotised brown anterior margin to costal vein; apex of fore wing with diffuse, weak brown infuscation, extending from approximately apical cell 4. Hind wing with white opaque plaga extending along margin of veins 3A and weakly along vein 2A, with pale brown infuscation centrally in anal cell 3; four to five apical cells.

Legs. Fore coxae with broad and somewhat irregular dark brown fasciae covering much of anterior and lateral faces, otherwise pale sandy-brown; mid coxae pale sandy-brown, lateral faces mostly deep brown; hind coxae pale sandy-brown; fore trochanters and femora with broad, dark brown fasciae on anterior and posterior faces, otherwise pale sandy-brown; mid and hind trochanters pale sandy-brown; mid femora pale sandy-brown with irregular brown fasciae on anterior faces; hind femora mostly pale sandy-brown with pair of weakly developed, pale brown fasciae along posterior faces; fore tibiae and tarsi mainly dark brown; mid and hind tibiae and tarsi pale sandy-brown with scattered small brown irregular patches; claws sandy-brown to brown, darkest apically.

Opercula. Relatively elongated, distal and medial margins broadly rounded and gently inclined towards abdominal midline; pale sandy coloured with two small, weak pale brown markings near basal crests; basal half of opercula convex, broadly dome-like; spikes on meracantha narrow and sharply pointed, only slightly overlapping opercula plate; operculum not quite reaching anterior margin of sternite II in lateral view.

Timbals. Long ribs 1-3 fused ventrally, and dorsally to basal spur; long rib 4 fused dorsally to basal spur; long rib 5 not extending across timbal plate to narrowed mid region of long rib 4; no anterior short rib, 3 short ribs only; elongated, narrow dome on timbal plate with distinct ridges, approximately parallel to long ribs.

Abdomen. Maximum width across tergite 3 slightly greater than across auditory capsules; in dorsal view, abdomen tapering posteriorly from tergites 3-8. Tergite 2 shiny black with narrow pale sandy-brown posterior margin, black colouration extending to and enclosing deep brown auditory capsules; tergite 1 black between timbals; tergites 3-8 with clearly defined mid-dorsal, black patches giving overall appearance of a broad, black dorsal fascia; each individual patch tending to widen posteriorly, but not quite reaching intersegmental membrane; ventrolateral margin of tergite 2 with deep brown, irregular patch extending across tergite but not intersegmental membrane; tergites otherwise pale sandy-brown with narrow, pale orange bands lining anterior margins of intersegmental membranes of tergites 3-7. Sternites II-VIII uniformly pale sandy-brown except for a small deep brown to black area located medially between sternites II and III.

Genitalia. (Fig. 12) Pygofer black dorsally grading to dark brown mid-laterally, otherwise pale sandy-brown grading to brown on upper lobes. Upper pygofer lobes in lateral view broad, gently decurved, apically moderately rounded but posteroventral corner more acutely-rounded; aedeagus with moderately long, but gently curved theca, sharply pointed and ornamented apically, with complex sclerotised curved flanges; pseudoparameres very small, originating near thecal base.

FEMALE. (Plate 2D) Overall colouration and markings very similar to male except genae shiny black with distinct sandy-brown margins. Mesonotum with black lateral sigillae narrowing and posteriorly extending into area between anterior and posterior arms of cruciform elevation; pale sandy-brown lateral mesonotal margins and zones between lateral and submedial sigillae broader. Legs markings similar to male, but extent and intensity of brown fasciae reduced. Abdomen: tergite 2 black dorsally extending and narrowing ventrally along anterior margin, just reaching auditory capsule, dorsal halves of which are dark brown; remaining colour medium orange-brown; black anterior bands on tergites

3-8 expanded dorsally, becoming progressively reduced in width and dorsal extent towards tergite 8; tergites 3 and 4 with small brown lateral patches; remaining colouration of tergites 3-7 pale to medium orange-brown, browner towards ventral margins; remaining colour of tergite 8 paler; tergite 9 with broad, black, dorsal fascia, somewhat irregular in shape, sharply narrowing to a point posteriorly; rest of tergite sandy-brown, becoming paler ventrally, with small medium-brown, diffuse spot (stigma) submedially, approximately two-thirds along length of tergite. Sternites uniformly pale sandy-brown. Distinct brown, anterior infuscation on hind wing anal cells 2 and 3. Ovipositor sheath extending ~0.8mm beyond apex of tergite 9.

MEASUREMENTS. N = 14♂, 1♀. Ranges and means (parentheses). *BL*: ♂ 10.7-12.4 (11.5); ♀ 11.0. *FWL*: ♂ 11.3-13.0 (12.1); ♀ 12.7. *HW*: ♂ 2.9-3.3 (3.1); ♀ 3.4. *PW*: ♂ 3.3-3.6 (3.4); ♀ 3.5. *AW*: ♂ 3.6-3.9 (3.7); ♀ 3.6. *FWL/BR*: ♂ 2.40-2.63 (2.54); ♀ 2.55.

DISTRIBUTION, HABITAT AND BEHAVIOUR. (Fig. 5) Known from the highlands of the Mt Moffatt section of Carnarvon NP, including the adjacent Chesterton Range, southern-central Queensland. Specific localities include the Park Headquarters, "The Tombs", North-west Road, and near Marlong Arch. It is found in grassland, including spinifex, associated with open eucalypt woodland. The associated soils are shallow quartzose sands and boulders, with local alluvial derived sandy soils. These are derived from Jurassic quartz sandstones of the Precipice sandstone and Boxvale Sandstone Formations. This cicada is a cryptic and mobile species. Its song, which is quite distinct from the previously described *Graminitigrina* species, is described in detail below in the song descriptions. The available records range from November to January, following significant rains.

ETYMOLOGY. Derived from Carnarvon National Park, in which the type locality is located.

***Graminitigrina triodiae* sp. nov.**

(Figs 5, 13, 14, 36-40, Plate 2E-F, Table 6)

Urabunana sp.: Dunn, 2002: 26-27.

MATERIAL. HOLOTYPE: ♂, QMT133336, 1.6km NNE Microwave Tower, Canns Camp track, Burra Ra., ~16km E. Torrens Ck, N.Q., AE, 6 Feb 2006. 20°42.82'S 145°10.63'E, Photog. Spm PS1572.

PARATYPES. 1♂, same data as holotype, 5.ii.2006, recorded (box); 15♂, 1♀, same data as holotype; 1♂, same data, recorded (box); 3♂, 1♀, same data, 7.ii.2006; 1♂, 1♀, same data, 8.ii.2006 (AE). 1♂, same data,

8.ii.2006; 1♀, same data, 6.ii.2006 (ANIC). 1♂, same data, 8.ii.2006 (BMNH). 1♂, same data, 8.ii.2006 (MSM). 1♂, Burra Range Telecom Tower, N. Qld., 12.ii.1994, K.L. Dunn & M.F. Braby (JM). 1♂, 1♀, same data (KLD).

DESCRIPTION. (Male). Figs 13, 14, Pl. 2E. *Head.* Supra-antennal plate and vertex shiny black with 2 small brown spots anteriorly, adjacent to pedicels of antennae; short triangular sandy-brown fascia extending from between lateral ocelli, widening towards and extending to posterior margin of head; short sparse dorsal golden pubescence. Postclypeus, including dorsal surface, shiny black with small, pale sandy spot dorsally on midline and sandy-brown margin which extends only slightly along transverse grooves; scattered short golden pubescence; mandibular plate and genae shiny black with long and short golden pubescence. Ocelli rose red. Compound eyes medium to dark brown. Anteclypeus shiny black covered by short golden pubescence, especially along lateral margins; rostrum medium brown grading to black apically. Antenna black to deep brown with brown pedicel.

Thorax. Pronotum shiny black, pale sandy-brown along lateral margins, extending and narrowing anteriorly to beneath posterior margins of compound eyes; sandy-brown central fascia extending to and narrowing towards anterior pronotal margin, but not reaching posterior margin; pronotal collar shiny black with very narrow sandy posterior edges; lateral angles of pronotal collar markedly ampliate; pronotum with short golden pubescence. Mesonotum predominantly black due to nearly complete coalescence of black submedian sigillae with very broad black lateral sigillae, separated only by a narrow, brown, curved line that extends to apices of anterior arms of cruciform elevation; black colouration extending between anterior arms of cruciform elevation; lateral mesonotal margins pale sandy-brown, extending to wing grooves; cruciform elevation pale yellow-orange grading to sandy-brown toward posterior margin; areas between anterior and posterior arms of cruciform elevation black anteriorly, pale sandy-brown posteriorly.

Wings. Venation pale sandy-brown becoming dark brown towards and around apical cells; costal vein translucent with pale brown colouration developed distally, very narrow, brown sclerotised anterior margin; apex of fore wing with distinct brown infuscation extending, although paler, to approximately apical cell 5 and ulnar cells 1 and

TABLE 6. *Graminitigrina triodiae* - summary of calling and ratchet song parameters. Data compiled from separate field and container recordings of five insects (Burra Range).

	Calling Song		
A. Chirp phrases			
(i) Chirp lengths (ms) -			
7 diposyllables - field recordings	190(177-210) ⁽¹⁾		
8 diposyllables - field recordings	202(148-225) ⁽¹⁾		
9 diposyllables - field recordings	219(183-252) ⁽¹⁾		
9 diposyllables - container recordings	340(255-386) ⁽¹⁾		
10 diposyllables - field recordings	266(251-281) ⁽¹⁾		
10 diposyllables - container recordings	376(305-436) ⁽¹⁾		
11 diposyllables - container recordings	359(354-363) ⁽¹⁾		
(ii) Chirp repetition rates (ms)			
Field recordings	374(233-445)(1)[2.7 Hz(4.3-2.2Hz)] ⁽²⁾		
Container recordings	623(529-744)(1)[1.6 Hz(1.9-1.3Hz)] ⁽²⁾		
B. Click phases (= diposyllables)			
(i) Inter-diposyllable intervals (ms)			
Diposyllables per chirp	8 diposyllables	9 diposyllables	10 diposyllables
Diposyllables - 1 to 2	49.5(43-57)[20 Hz] ⁽²⁾	55.1(44-66)[18 Hz] ⁽²⁾	49.1(45-59)[20 Hz] ⁽²⁾
2 to 3	38.0(32-44)[26 Hz] ⁽²⁾	37.4(34-39)[27 Hz] ⁽²⁾	42.8(41-45)[23 Hz] ⁽²⁾
3 to 4	29.9(27-33)[33 Hz] ⁽²⁾	29.2(23-32)[34 Hz] ⁽²⁾	36.4(35-38)[27 Hz] ⁽²⁾
4 to 5	24.1(23-26)[41 Hz] ⁽²⁾	24.1(20-26)[41 Hz] ⁽²⁾	30.9(29-33)[32 Hz] ⁽²⁾
5 to 6	20.2(19-22)[50 Hz] ⁽²⁾	20.6(18-22)[49 Hz] ⁽²⁾	26.1(25-27)[38 Hz] ⁽²⁾
6 to 7	16.2(15-17)[62 Hz] ⁽²⁾	17.0(14-18)[59 Hz] ⁽²⁾	22.4(22-23)[45 Hz] ⁽²⁾
7 to 8	14.4(14-15)[69 Hz] ⁽²⁾	13.1(11-14)[76 Hz] ⁽²⁾	18.6(18-19)[54 Hz] ⁽²⁾
8 to 9	-	12.4(11-14)[81 Hz] ⁽²⁾	15.1(13-17)[66 Hz] ⁽²⁾
9 to 10	-	-	14.0(13-15)[71 Hz] ⁽²⁾
(ii) Diposyllable structures			
Inter-hemisyllable intervals (ms)	4.1(3.5-5.1)(1)[244 Hz] ⁽²⁾		
Lengths of initial hemisyllables (ms)	0.93(0.64-1.3) ⁽¹⁾		
Lengths of second (dominant) hemisyllables (ms)	3.5(3.3-3.6) ⁽¹⁾		
Total lengths of diposyllables (ms)	7.6(6.8-8.8) ⁽¹⁾		
C. Dominant frequency (kHz)			
	8.15 (7.95-8.55) ⁽¹⁾		
D. Click phases (=diposyllables)			
Ratchet Song			
(i) Repetition rates (ms)	36.3(27-45)(1)[27.5 Hz(37-22Hz)] ⁽²⁾		
(ii) Diposyllable structures			
Inter-hemisyllable intervals (ms)	3.6(3.4-3.7)(1)[278 Hz] ⁽²⁾		
Lengths of initial hemisyllables (ms)	1.5(0.84-2.0) ⁽¹⁾		
Lengths of second (dominant) hemisyllables (ms)	3.7(3.3-4.0) ⁽¹⁾		
Total lengths of diposyllables (ms)	7.2(7.0-7.4) ⁽¹⁾		
Lengths of high amplitude pulse doublets (ms)	0.76(0.73-0.81) ⁽¹⁾		
E. Dominant frequency (kHz)			
	8.08 (7.90-8.30) ⁽¹⁾		

⁽¹⁾Figures are means and (ranges). ⁽²⁾Equivalent frequency values [Hz] of ranges or means.

⁽¹⁾Figures are means and (ranges). ⁽²⁾Equivalent frequency values [Hz] of ranges or means.

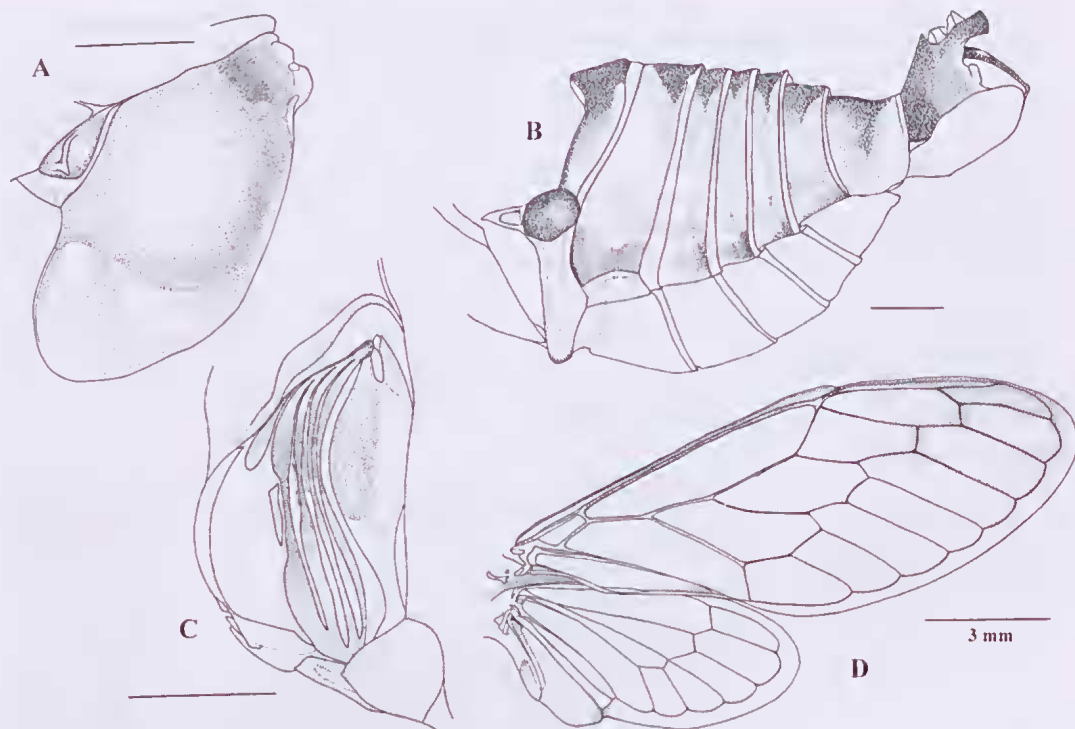


FIG. 13. *Graminitigrina triodiae* sp. nov. Burra Range section of White Mountain National Park. A, right operculum; B, lateral abdomen view; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

2. Hind wing with off-white to pale brown plaga extending along margins of vein 3A; small brown infuscation at apex vein 3A, extending slightly proximally along vein; veins 2A and especially 3A distinctly orange-brown; 5 apical cells.

Legs. Fore coxae with most of anterior face dark brown to black; lateral faces with central deep brown to black fascia, otherwise pale sandy-brown; mid and hind coxae mostly deep brown to black, apices pale sandy-brown; fore trochanters and femora with deep brown to black fasciae on anterior and posterior faces, otherwise sandy-brown to brown; mid and hind trochanters pale brown with small deep brown patches especially on anterior faces; mid and hind femora pale sandy-brown to brown with black to deep brown fasciae along posterior faces; fore tibiae and tarsi mainly black to deep brown; mid to hind tibiae and tarsi pale brown to brown, with dark brown fasciae along dorsal margins, bases and apices of tarsi deep brown; claws brown.

Opercula. Slightly elongated, disto-medial margins slightly tapered and rounded, gently inclined towards abdominal midline; opercula sandy-brown with clearly defined black patch near basal crests; basal two thirds of operculum strongly convex, domed; spikes on meracantha small, sharply pointed, not extending across opercula plates; distal operculum gently undulate, not reaching anterior margin of sternite II in lateral view.

Timbals. Long ribs 1-4 fused ventrally, and dorsally to basal spur; long rib 5 very short but robust, not extending ventrally near anterior short rib; long rib 4 especially broad and robust, much more so than long ribs 1-3; anterior-most short rib robust, short ribs between long ribs 1-4 very thin and relatively poorly sclerotised; unusually large area of uninterrupted white resilin on timbal plate extending from long rib 4 to anterior timbal margin; narrow dome on timbal plate with distinct ridges.

Abdomen. Maximum width across tergite 3 slightly greater than across auditory capsules;

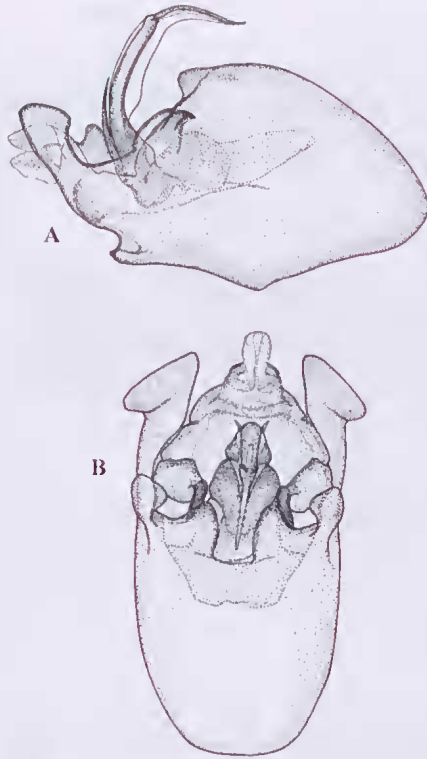


FIG. 14. *Graminitigrina triodiae* sp. nov. Pygofer and male genitalia, lateral (A) and ventral views (B). Specimen from Burra Range section of White Mountains National Park. Length of pygofer, 2.6mm.

in dorsal view, abdomen progressively tapering posteriorly from tergites 3-8. Tergite 2 shiny black to deep brown, with narrow sandy-brown posterior margin; dark colouration extending to and covering auditory capsules, central regions of which are deep brown; tergite 1 shiny black to deep brown between timbals; tergites 3-8 with clearly defined black to deep brown mid-dorsal patches; individual patches widest medially, narrowing both anteriorly and posteriorly, reaching but not extending posteriorly across intersegmental membranes; dark patches decreasing in size and intensity from tergite 3-8; ventrolateral margins of tergites 3-7 with irregular patches of deep brown to brown colouration, becoming smaller and weaker in intensity on tergites 6 and 7; tergites 3-7 otherwise sandy-brown to brown, becoming orange brown along the posterior half of each tergite; intersegmental membranes conspicuously pale yellow-brown; tergite 8 mostly sandy-brown, with darker dorsal area. Sternites II to VIII pale sandy-brown, slightly more intense along

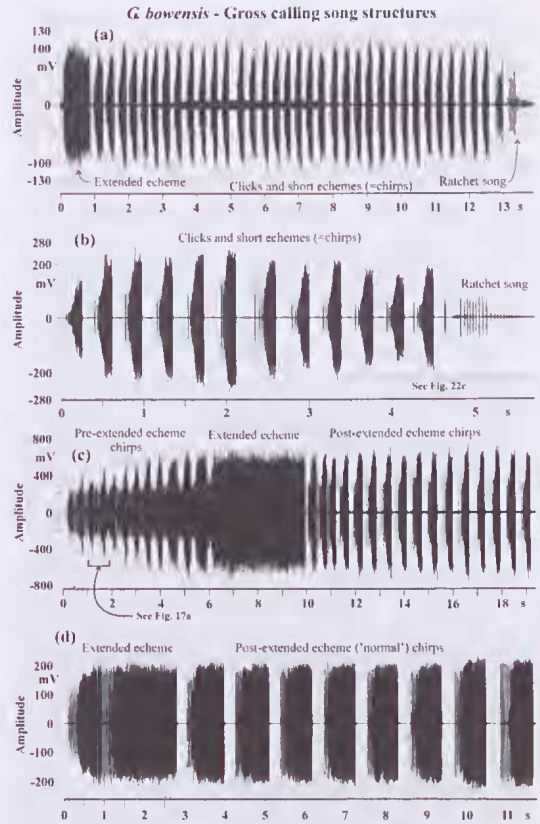


FIG. 15. *Graminitigrina bowensis* sp. nov. Waveform plots showing gross temporal structures of calling songs; (a, c, d), extended echemes; (c), pre-extended echeme chirp phrases; (a-d), post-extended echeme chirp phrases; (b), ratchet song. Recordings (a-c) of insects from Flagstaff Hill, Bowen; (a-b), field recordings with parabola, filtered (IIR) to 8 kHz; (c), unfiltered container recording; (d), unfiltered container recording of insect from Croydon.

intersegmental membranes; small black median area on sternite II just extending to sternite III.

Genitalia. (Fig. 14) Pygofer shiny, black dorsally grading to deep brown laterally and posteriorly; upper pygofer lobes in lateral view broad, decurved, apices expanded and rounded. Aedeagus with gently curved theca, curvature more pronounced and gently sinusoidal distally, apex not significantly ornamented but with four very small pairs of spines; poorly sclerotised, but distinct flange along inner curved surface, and inconspicuous, poorly sclerotised flange along outer curved margin of theca; pair of short, but clearly defined pseudoparameres, originating near thecal base.

FEMALE. Pl. 2F. Similar to male in overall colouration and patterning except: head with narrow sandy-brown anterior margin along supra-antennal plate and vertex, more conspicuous pale sandy-brown midline on anterior face of postclypeus; genae with narrow sandy-brown lateral margins; pronotum shiny black with broader pale sandy-brown central fascia extending from anterior to posterior margin, splaying out along posterior margin. Mesonotum with narrower black lateral sigillae which extend to anterior arms of cruciform elevation; submedian sigillae more clearly defined, fused medially, resulting narrower median black fascia extending and widening posteriorly to between anterior arms of cruciform elevation; sandy-brown areas between sigillae more extensive. Legs markings similar to male but dark fasciae reduced in area and intensity. Abdomen: tergite 1 medium brown dorsally; tergite 2 with black dorsal area which narrows and extends submedially along anterior margin and does not extend to auditory capsule; rest of tergite 2 and auditory capsule pale sandy-brown; tergites 3-8 with black dorsal patches (often more clearly defined than in males), that become progressively smaller in area towards tergite 7; dark patches not extending across intersegmental membranes on tergites 3-6, and not reaching intersegmental membrane on tergite 7; patch on tergite 8 distinctly transverse, extending laterally along anterior margin; small and relatively inconspicuous brown markings along ventro-lateral margins of tergites 3-5, becoming smaller and paler towards tergite 5; tergites 3-8 mainly sandy-brown laterally and submedially along anterior margins, becoming a conspicuous chestnut-brown submedially along posterior margins and extending to intersegmental membranes; the latter are sandy-brown on tergites 3 to 6; tergite 9 with pair of broad, irregular-shaped submedian fasciae of very variable brown colouration, tending to be darker posteriorly; fasciae extend to, and coalesce near posterior margin of tergite; a small, submedian, brown spot situated towards posterior of tergite; tergite 9 colouration dominantly sandy-brown to brown dorsally, with localised chestnut-brown area along disto-ventral margins. Sternites pale sandy-brown. Ovipositor sheath black distally, extending 0.9-1.2mm beyond apex of tergite 9.

MEASUREMENTS. N = 25♂, 4♀. Ranges and means (in parentheses). BL: ♂, 11.0-14.1 (12.6); ♀, 12.2-13.5 (12.6); FWL: ♂, 11.7-14.0 (13.2); ♀, 13.0-13.7 (13.3); HW: ♂, 3.0-3.6 (3.3); ♀, 3.3-3.5 (3.4); PW: ♂, 2.6-3.2 (3.0); ♀, 2.9-3.2 (3.1); AW: ♂, 4.0-4.6 (4.3);

♀, 3.6-4.0 (3.8); FWL/BR: ♂, 2.43-2.65 (2.53); ♀, 2.41-2.48 (2.46).

DISTRIBUTION, HABITAT AND BEHAVIOUR. (Fig. 5) Known only from the upland desert plateau area (Alice Tableland Province) of the Burra Range section of White Mountain National Park, approximately 16km E of Torrens Creek township, northern Queensland. The specific habitat is developed on a ferruginous sand plain, overlying a laterite profile, itself developed on quartzose sandstones and siltstones of the Warang Sandstone Group of probable Triassic age. The vegetation is dominated by *Eucalyptus similis* Maiden woodland with spinifex understory (*Triodia pungens* R. Br.) on which this cicada is restricted. In common with other *Graminitigrina* species, adults are very wary, mobile and fast flying. Singing occurs in the morning, the time of initiation and cessation depending on specific weather conditions. When sunny, singing starts at approximately 0730 hrs and continues, becoming progressively more sporadic, until late morning. When part cloudy, singing starts and finishes later, extending sporadically to mid afternoon. Adults are superbly cryptic, and when physically touched, drop down into the spinifex where they are completely concealed. Dunn (2002) provides a description of the mating behaviour, including wing flicking (or 'clapping'). Available records, during which active emergence was occurring, are only for February. Although the type series was collected from one specific locality in the Burra Range, aural records indicate that it occurs, albeit in very localised populations over 3.1km along the Canns Camp track in the Burra Range NP. This species, as further noted below in the song descriptions, has close similarities to *G. carnarvonensis*. It is of significance to note that both occur on the Great Dividing Range, on soils developed on sandstone basements, although separated by a linear distance of 550km.

ETYMOLOGY. From *Triodia*, the generic name of the spinifex grass on which this species is found.

ANALYSES OF THE SONGS OF *GRAMINITIGRINA* CICADAS

Species of *Graminitigrina* cicadas tend to separate into three groups according to their songs; the two northern species (*G. karumbae* and *G. bowensis*); *G. bolloni*; and *G. carnarvonensis* and *G. triodiae*. The calling songs of both *G. bowensis* and *G. karumbae* are dominated by distinctive sharp, repetitive chirp phrases, superficially similar in gross structures. The songs of *G. bowensis*,

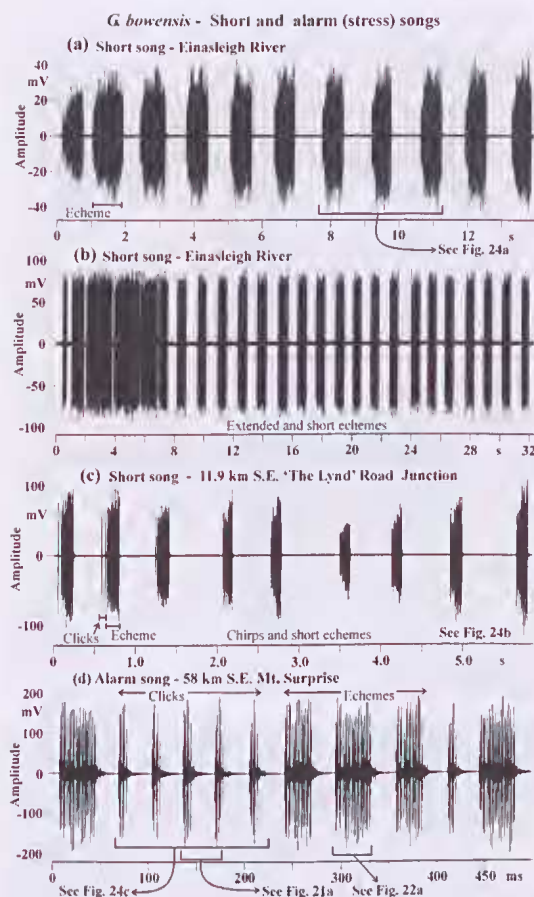


FIG. 16. *Graminitigrina bowensis* sp. nov. Waveform plots of short songs (a-c) and alarm song (d). In the short songs, sets short echemes, of variable lengths, with either very few or more usually no preceding clicks are shown. The chirps in (c) are from the end of a sequence. The alarm song shows clicks and very short echemes which exhibit no regular temporal pattern of emission. Data in plots (a-b), filtered (HR) to 0.5 kHz; (c-d), unfiltered. (a-b), container recordings from Einasleigh River crossing (W. of Mt Surprise); (c), container recording from 11.9km SE of "The Lynd" road junction; (d), open net recording in the field from 58km S.E of Mt Surprise.

however, exhibit variability, some of which appears to be regional. This is most notable in the population from Flagstaff Hill at Bowen (type locality) in which the calling song possesses an additional extended sharp buzzing phrase, referred to here as an 'extended echeme'. This song phrase is very common in the Bowen population, and has been observed in the Croydon population, but has not been encountered in other populations of

this species, or in *G. karumbae*. As documented below, songs of *G. bowensis* show three additional song variants, the 'short song', the 'alarm (stress) song', and the 'ratchet song'. This latter song type has been observed in four of the species of *Graminitigrina* (*G. carnarvonensis* the exception), although electronically recorded only for *G. bowensis* and *G. triodiae*. *Graminitigrina bolloni*, *G. carnarvonensis* and *G. triodiae* have songs comprising repetitive sequences of short chirps and clicks, with distinctive temporal characteristics that clearly differentiate them from *G. bowensis* and *G. karumbae*.

Graminitigrina species are generally restricted to rough grassland, including spinifex and low heath, within open, sometimes disturbed woodland. The dominant yellowish and black colouration of adults merges well with the associated green/brownish-yellow grass and heath vegetation. Adults sit and sing on grass stems at all levels, often among seed clusters, or within foliage of the heath. Calling songs extend for 1 to 2 minutes, or slightly longer. The adults then abruptly cease their calling songs, which are then replaced by the 'ratchet song' (excepting *G. carnarvonensis*) which continues as the cicada flies to a new singing location; then calling song emission is again initiated. This 'sing and fly' behaviour occurs from early morning (about 0730 hrs a.m.) in open sunny conditions, and continues to mid morning, with song production becoming more sporadic towards late morning, and ceasing altogether by midday to early afternoon. In between singing periods, and after singing has ceased, the cicadas sit quietly and cryptically, presumably feeding in the grassland/heathland, with no obvious movement unless disturbed.

SONG DESCRIPTIONS

1. *G. bowensis*

Four song types are recognised in this species: (a) The **normal calling song**, referred to above, consisting of repeated chirps, with an additional **extended ('buzzing') echeme**, usually, but not always preceding the repeated chirp song phase (Fig. 15a-c). The extended echeme is a characteristic feature of the songs of the Bowen population, but has also been noted in the Croydon population (Fig. 15d). (b) Sporadically emitted short sequences of rapidly emitted chirps, referred to here as the '**short song**', sometimes with embedded, slightly longer echemes (Fig. 16a-c). This song type has only been encountered twice, each in populations very low in numbers and

believed to be in decline. In these situations, adults appeared to be relatively sedentary, calling with sporadic, short and sharp song sequences, with or without flight. (c) A distinctive alarm (stress) call, given when an adult is trapped in a spider web, or relatively tightly confined within a net (Fig. 16d). This song consists of a monotonous, continuous sequence of rapidly repeating clicks and short chirps. (d) The ratchet song accompanying flight to a new song location (Fig. 15a, b). Parameters of each song type are listed in Table 2.

1A. Calling Song.

Bowen locality. The extended ('buzzing') echeme phase occurs either at the beginning or later during the song, and lasts from approximately 1 to 7.5 s, and is preceded by (except where occurring at start of song) and followed by sequences of continuous short, rapid chirps (Fig. 15). Each 'chirp phrase' consists of a set of discrete clicks which progressively merge and coalesce to form a short 'chirp echeme' which increases in amplitude during emission. The chirp phrases that precede the extended echeme phase actually differ in detailed temporal characters from those chirp phrases that follow the extended echemes. Descriptions that follow therefore distinguish pre- and post-extended echeme chirps. This latter chirp-type constitutes the typical chirp calling songs that are emitted without any accompanying extended echeme phase.

(i) *Pre-extended echeme chirp phrases.* (Table 2; Figs 15c; 17a-c). These consist of a series of repeated short echemes, each showing progressively increasing amplitude and increasing length, the latter ranging from 0.21 to 0.49 s. Between each short echeme occur sets of continuous clicks, 7 to 10 in number, whose repetition rates become sequentially more rapid both towards the following extended echeme, and towards each following short echeme. Click repetition rates range between 26 s^{-1} (initial set) to 59 s^{-1} in the final sets immediately prior to the extended echeme. These compare with short chirp echeme repetition rates of 1.5 to 2.5 s^{-1} , these decreasing as the extended echeme is approached.

Each click, details of which are shown in the expanded waveform plot (Figs 17b), is interpreted to comprise 2 syllables, the click thereby representing a single macrosyllable. In some click macrosyllables, the structures suggest a third syllable (as in Fig. 17b), but based on examination of many such click macrosyllables, two syllables

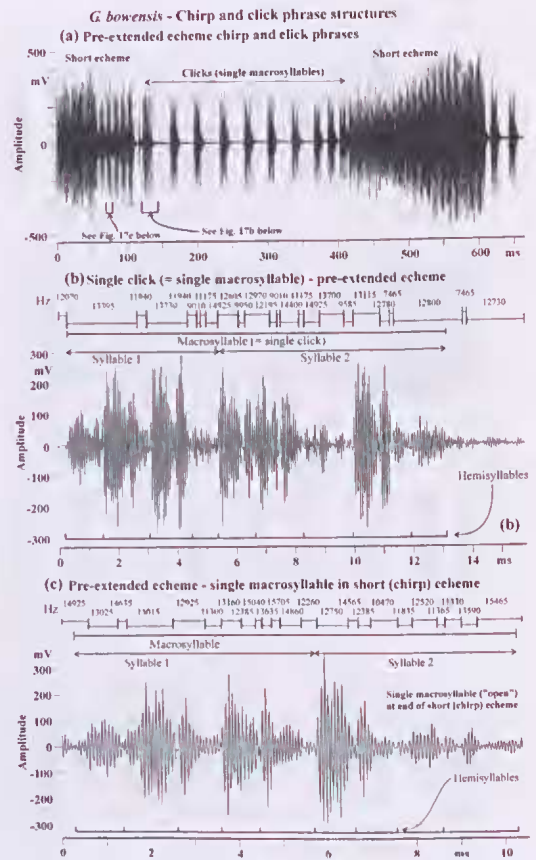


FIG. 17. *Graminitigrina bowensis* sp. nov. Pre-extended echeme chirp phrases. (a), waveform plot showing sequence of clicks between adjacent short chirp echemes. High resolution time expanded waveform plots of; (b) a single click (see location in (a) above) showing details of syllable and hemisyllable structures; and (c), a single macrosyllable within a short echeme (pre-extended echeme chirp phrase; see location in (a) above). (b) and (c) show the sequential changes in pulse frequencies as measured from detailed pulse counts. These are tabulated within the marked segments above each plot. Container recordings from Flagstaff Hill, Bowen filtered (IIR) to 0.5 kHz.

are here considered the most consistent. Each syllable is resolved into 4-5 hemisyllables. The initial hemisyllable tends to be relatively low amplitude, while partial overlap of adjacent hemisyllables is common. Low amplitude hemisyllables also occur, apparently compressed between adjacent higher amplitude hemisyllables, their relative positions within each macrosyllable being consistent relative to the same sets of hemisyllables in other macrosyllables. Syllable lengths

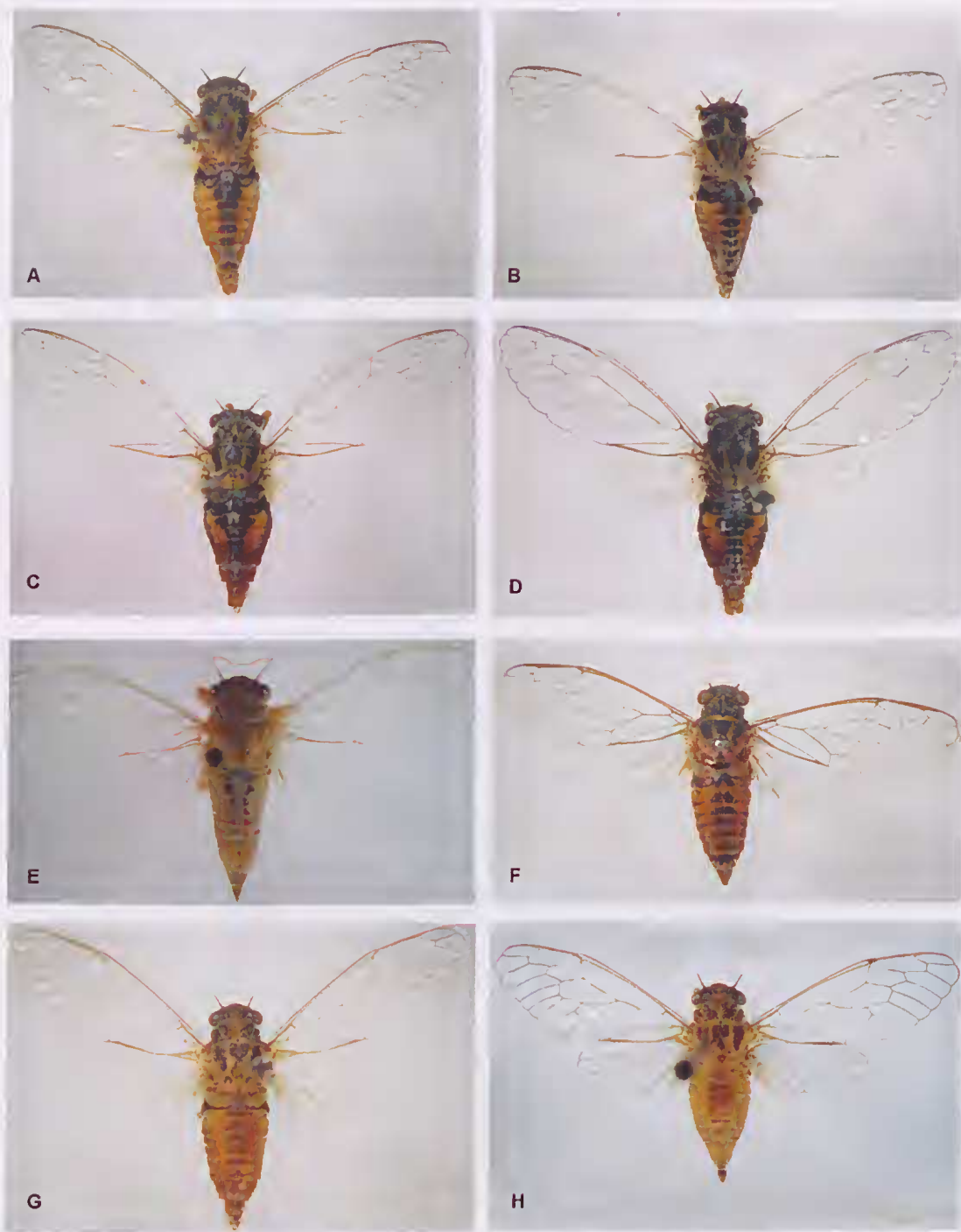


Plate 1. A–E, *Graminitigrina bowensis* sp. nov. A, holotype male, Flagstaff Hill, Bowen; B, male, Croydon. Total body lengths 12.6 and 12.2mm, respectively; C, male, Einasleigh River crossing, 35km W. Mt Surprise; D, male, 11.9km SE “The Lynd” Road junction; E, female, Flagstaff Hill, Bowen. Total body lengths 12.2, 11.2 and 11.7mm, respectively; F–H, *Graminitigrina karumbae* sp. nov. F, male, 10.7km E. Heathlands, Northern Cape York peninsula; G, holotype male, 2km E. Karumba Village, Karumba, southeastern Gulf of Carpentaria; H, female, 2km E. Karumba Village, Karumba. Total body lengths 12.7, 13.0 and 11.2mm, respectively.

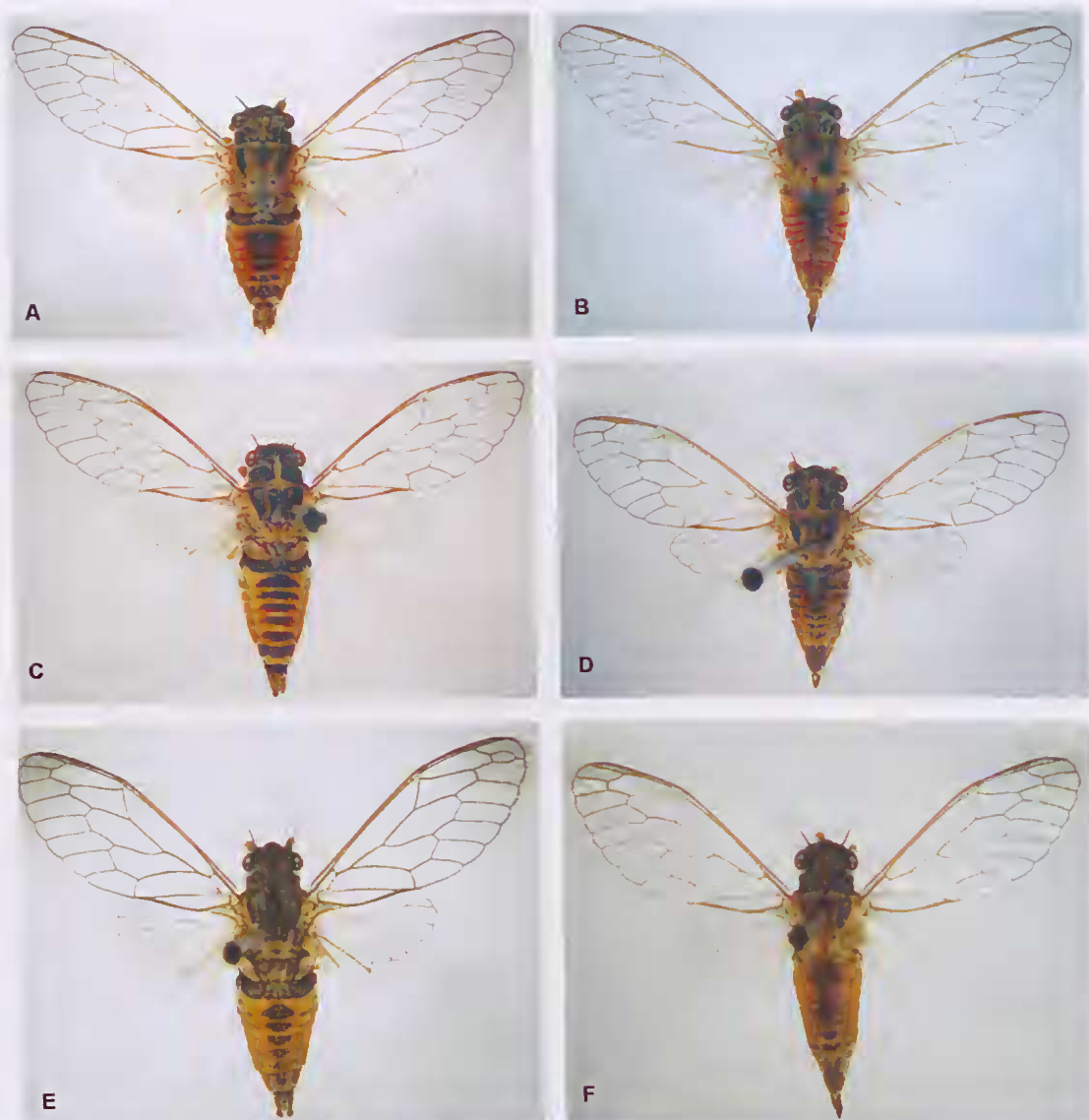


Plate 2. A–B, *Graminitigrina bolloni* sp. nov. A, holotype male; B, female, Both from 0.7km E. Bollon. Total body lengths 12.1 and 12.7mm, respectively; C–D, *Graminitigrina carnarvonensis* sp. nov. C, holotype male, Marlong Arch, Mt Moffatt National Park; D, female, Park Headquarters, Mt Moffatt National Park. Total body lengths 11.9 and 11.0mm, respectively; E–F, *Graminitigrina triodiae* sp. nov. E, male; F, female. Both from Burra Range section of the White Mountain National Park, 1.6km NNE of Microwave Tower. Total body lengths 13.0 and 12.2mm, respectively.

range between 5.1–8.2 ms, and macrosyllables 13.0–14.1 ms.

Detailed measurements of the pulses shown in the waveform plots (e.g. Fig. 17b) reveal a wide range of measured frequencies ranging between 7465 to 16020 Hz, developed across time domains between 0.1–2.0 ms in length, consistent with frequencies exhibited by the amplitude

spectra (Fig. 23). The higher amplitude hemisyllables tend to exhibit higher frequencies compared to the inter-hemisyllable intervals and macrosyllable tails. Of particular note are the rapid frequency changes on time scales of <1 ms.

Macrosyllable structures within the short chirp echemes (Fig 17c) are similar in structure to the click macrosyllables, again inferred to comprise

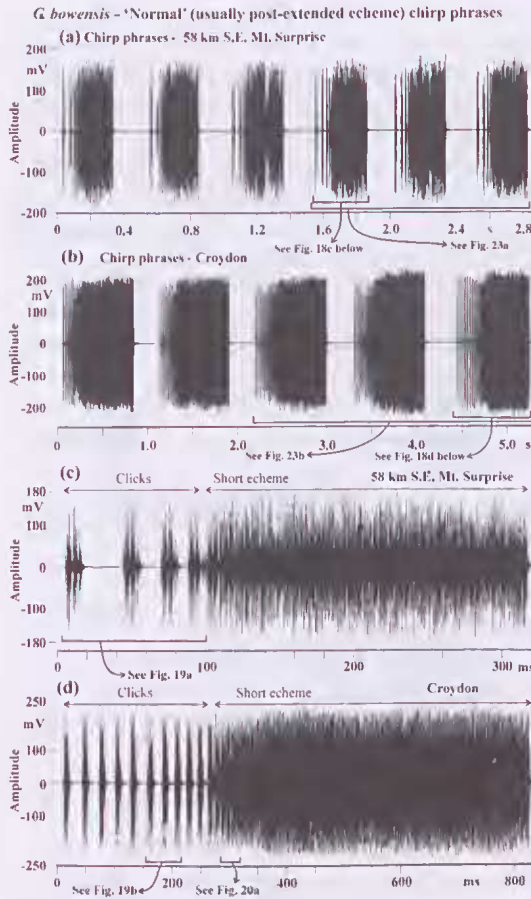


FIG. 18. *Graminitigrina bowensis* sp. nov. (a-b), Waveform plots of chrip phrases within calling songs that have no extended echemes (therefore equivalent to post-extended chrip phrases). These show the sequences of clicks preceding each short echeme. (c-d), Expanded time scales of selected segments from each of the previous plots of the clicks and their coalescing into the short echeme (locations shown in (a) and (b), respectively). Unfiltered container recordings. (a, c), from 58km SE Mt Surprise; (b, d), from Croydon.

2 syllables, each with 3-5 hemisyllables. Macrosyllable lengths range between 9.6-10.7 ms, shorter than observed for the clicks, while syllable lengths lie between 3.8-5.5 ms. Pulse measurements within the waveform plots indicate frequency ranges between 10470-15705 Hz, with the dominant, high amplitude hemisyllable phases between 12385-13160 Hz. The lower amplitude, inter-hemisyllable domains include both higher and lower frequencies. Again, rapid frequency fluctuations occur on time scales between 0.1-1.0 ms. The echeme structures are

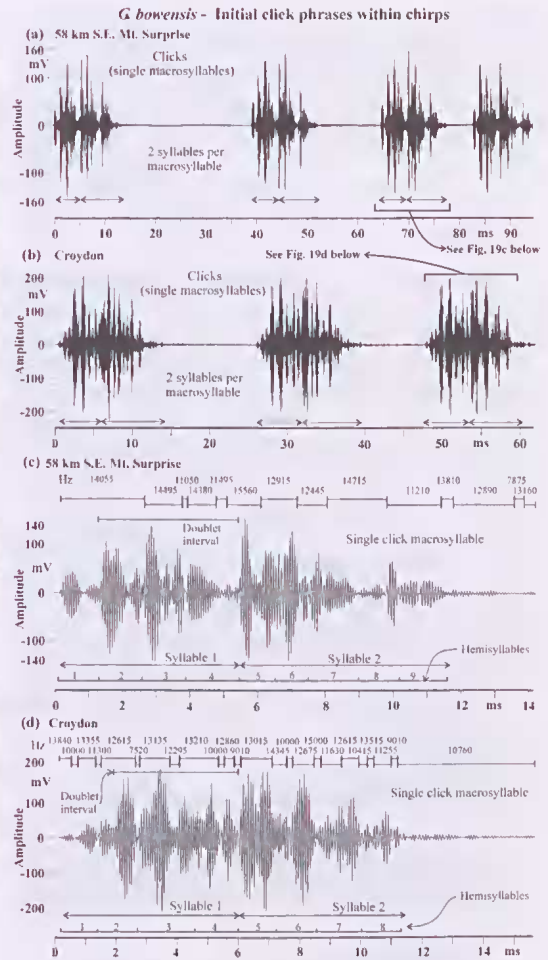


FIG. 19. *Graminitigrina bowensis* sp. nov. (a-b), time expanded waveform plots of click macrosyllables preceding the short echemes within a chrip phrase (post-extended echeme) of the calling song, showing the presence of two syllables within each macrosyllable, and the higher frequency carrier pulses. (c-d), high resolution time expanded waveform plots of individual click macrosyllables, showing detailed syllable wave structures, the definition of syllable intervals (shown by the arrowed lines in a-d) and doublet intervals (c-d), and the sequentially changing frequency domains measured from the detailed pulse structures (tabulated above each plot). Unfiltered container recordings. (a, c), 58km SE Mt Surprise; (b, d), Croydon.

interpreted to represent coalesced and slightly compressed click macrosyllables.

(ii) *Post-extended ('normal') echeme chrip phrases.* (Table 2; Figs 15, 18) These consist of sets of discrete clicks which progressively merge

and coalesce into the short chirp echemes, each increasing in amplitude during emission. The clicks range from 0 to 5 in number (rarely zero); chirp lengths range between 0.15–0.46 s, with repetition rates between 2.2–3.3 s⁻¹ (field parabola recordings in direct sunshine), compared to 0.9–2.85 s⁻¹ (container recordings); the highest rates occur closest to the preceding extended echeme, if present.

Detailed structures of individual clicks, shown in time expanded waveform plots (similar to those shown in Fig. 19a, b), suggest a single macrosyllable comprising two syllables (without intervening time gap), with four hemisyllables per syllable, each containing three dominant composite pulses. Macrosyllable lengths lie between 12.7–14.4 ms, syllables between 6.1–7.2 ms, and hemisyllables 0.83–1.7 ms, these values very similar to the pre-extended echeme clicks. Through progressive coalescence, the click macrosyllables merge into the short chirp echemes, each typically comprising between 15–40 macrosyllables. These are similar to those illustrated in Fig. 18c, d, and in Fig. 20b, in which each macrosyllable comprises two syllables, each

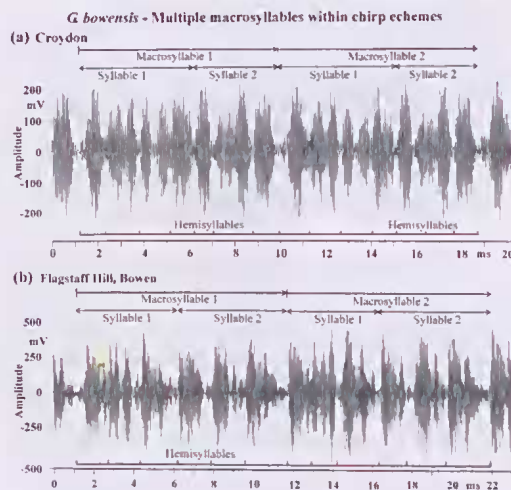


FIG. 20. *Graminitigrina bowensis* sp. nov. High resolution time expanded waveform plots of macrosyllable structures within short chirp echemes of calling songs (post-extended echeme) from (a), Croydon and (b), Flagstaff Hill, Bowen. In both plots, two coalesced macrosyllables are shown, each macrosyllable resolved into two juxtaposed syllables, each of which is further resolved into three to four hemisyllables. The higher frequency carrier pulses are also evident within the plots. Container recordings. (a), unfiltered; (b), filtered (IIR) to 0.5 kHz.

with 3–4 hemisyllables. Macrosyllable lengths range between 10.0–10.5 ms, syllable lengths between 4.6–5.7 ms, both notably shorter than observed in the clicks, consistent with syllable compression during coalescence.

(iii) *Extended echeme phase*. (Fig. 15a, d) This is very similar in overall syllable-hemisyllable structures to the short chirp echemes, emphasised by the comparative data listed in Table 2. The implication is that the extended echeme also

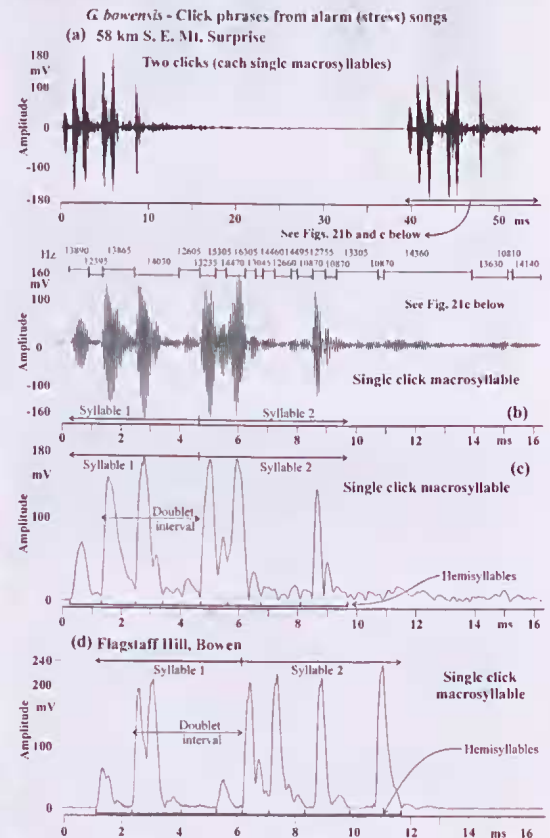


FIG. 21. *Graminitigrina bowensis* sp. nov. Higher resolution time expanded waveform plots (a–b) and envelope curves (c–d) of the clicks within stress song. (a) illustrates two click macrosyllables (locations shown in Fig. 16d), with the second click analysed in greater time expanded detail in (b–c). These show the two juxtaposed syllables, the defined doublet interval, and in (b), the rapid sequential frequency changes within the click macrosyllable, measured from the carrier wave pulse structures. (d), details of a single click of a stress song from Flagstaff Hill, Bowen, showing two coalesced syllables (compare with (c)). Unfiltered recordings made of insects constrained in a net in the field, from 58km SE Mt Surprise and Flagstaff Hill, Bowen.

represents a prolonged coalescence of click phrases.

(iv) *Song frequencies.* The amplitude spectra derived from multiple chirps are complex, with four groups of peaks commonly occurring between 10.5–11.4, 11.5–12.6, 12.7–13.7 and 14.1–14.9 kHz, with weaker peaks between 15.2–16.7 kHz, seen in both container and field recordings. The estimated dominant frequencies range between 12.6–13.6 kHz (mean 13.12 kHz), these close to the highest amplitude peaks seen in the spectra (e.g. Fig. 23c). The strongest frequency

peaks have a tendency to comprise peak doublets, although all peaks are broad due to the presence of numerous closely-spaced line spectra, inferred to represent sets of sidebands of variable frequencies (e.g. see tabulation in Fig. 23c).

1B. Calling Song

Inland localities. (Croydon, Einasleigh River, 58km SE Mt Surprise, and near 'The Lynd' Highway junction) Only in the Croydon population has an extended echeme phase been sporadically heard. The songs from these inland localities mainly comprise monotonously repeated chirp phrases (Figs 15d; 18a–d) whose lengths range between 0.13–1.6 s (Table 2) with repetition rates between 0.5–2.4 s⁻¹, tending to progressively increase, within a given song sequence, during song emission. As in the Bowen population, each chirp consists of a series of initial clicks (up to 21 in number, very rarely zero),

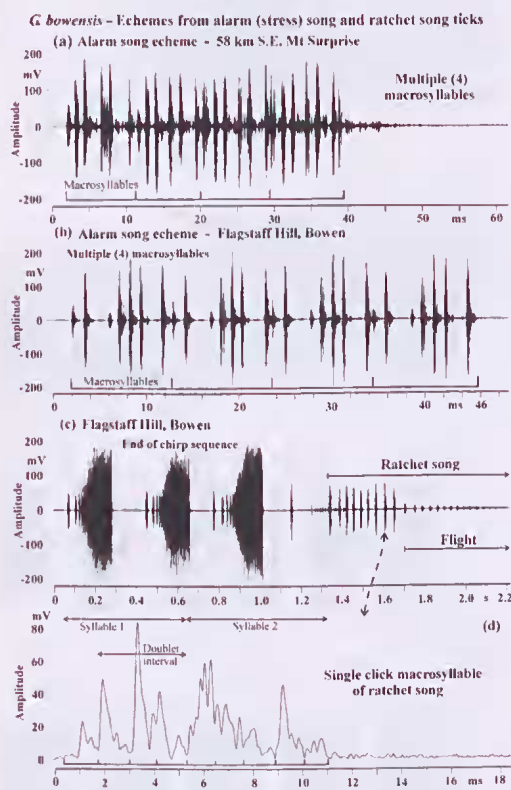


FIG. 22. *Graminitigrina bowensis* sp. nov. (a–b), time expanded waveform plots showing the structures of a single echeme within two alarm songs, each comprising four macrosyllables, from 58km SE Mt surprise (see location of echeme in Fig. 16d), and Flagstaff Hill, Bowen respectively. Unfiltered recordings of insects constrained in a net in the field; (c), waveform plot of ratchet song emitted at end of a normal chirp sequence, occurring immediately prior to, and during flight; (d), high resolution envelope curve showing details of a single click macrosyllable from the ratchet song in (c). (c–d), parabola field recordings from Flagstaff Hill, Bowen, filtered (IIR) to 8 kHz.

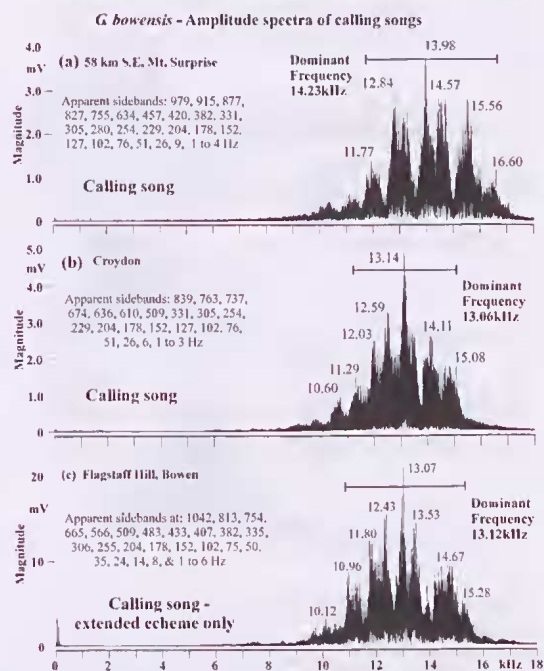


FIG. 23. *Graminitigrina bowensis* sp. nov. (a–e), Amplitude spectra of multiple chirps within calling songs from 58km SE Mt Surprise (see Fig. 18a), Croydon (see Fig. 18b), and Flagstaff Hill, Bowen (extended echeme), respectively. Frequencies of the main peaks are labeled, and the apparent sidebands, measured from the spectra, are tabulated. The horizontal bars indicate the high amplitude envelope of each spectrum used to estimate the dominant frequency of each song. Container recordings, unfiltered.

whose repetition rates increase during progressive emission, merging into the following short chirp echeme (Fig. 18e, d).

(i) *Clicks*. (Fig. 19) Detailed structures seen in time expanded waveform plots are similar to those of the Bowen population. Each click is similarly interpreted as a macrosyllable comprising two juxtaposed syllables, each syllable with 4 to 5 hemisyllables (each with 3 distinct composite

pulses). Lengths range between 8.9–11.6, 5.3–6.2, and 1.0–1.9 ms, respectively; the macrosyllable and syllable lengths are slightly shorter than measured in the Bowen songs. Detailed waveform plots show frequency ranges between 7520 to 15560 Hz (Fig. 19c, d), consistent with amplitude spectra (e.g. Fig. 23a, b), and again exhibit rapid frequency alternations on time scales of between 0.1–4.3 ms. The higher amplitude pulses exhibit frequencies in the higher measured ranges, the lower amplitude pulses tending to be characterised by more variable frequencies.

(ii) *Short chirp echemes*. (e.g. Fig. 20a) These comprise coalesced macrosyllables, with similar pulse structures to those in the clicks (compare Figs 19c, d and 20a). The individual macrosyllables are clearly resolved within the echeme structures, most pronounced in the early echeme structures (cf. Figs 19c, d; 20a).

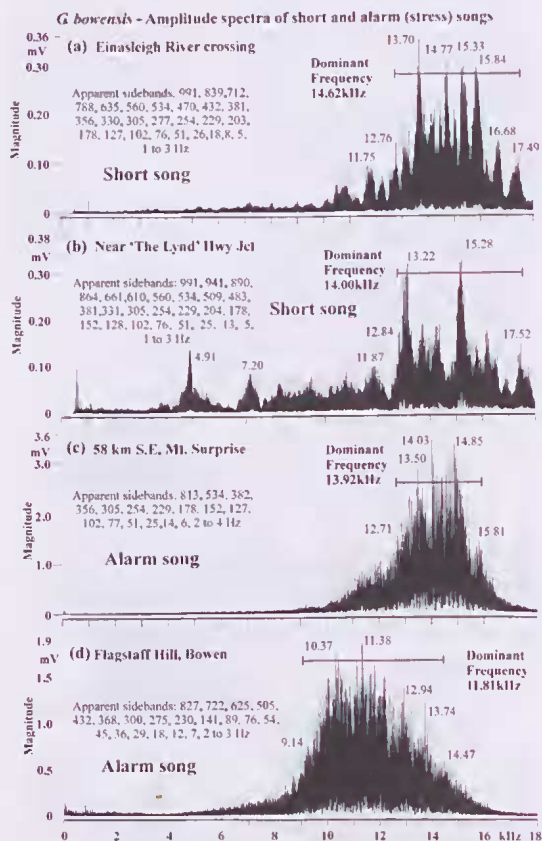


FIG. 24. *Graminitigrina bowensis* sp. nov. (a-b), amplitude spectra of short songs from, (a) Einasleigh River crossing, W. of Mt Surprise (see location in Fig. 16a); (b) 11.9 km SE of 'The Lynd' road junction, N. Queensland. Container recordings filtered (IIR) to 0.6 kHz (see location in Fig. 16c). (c-d), amplitude spectra of alarm songs, recorded from insects constrained in a net in the field, from (a), 58 km SE Mt Surprise (see Fig. 16d); (b), Flagstaff Hill, Bowen. Unfiltered data. Frequencies of the main peaks are labeled, and the apparent sidebands, measured from the spectra, are tabulated. The horizontal bars indicate the high amplitude envelope of each spectrum used to estimate the dominant frequency of each song.

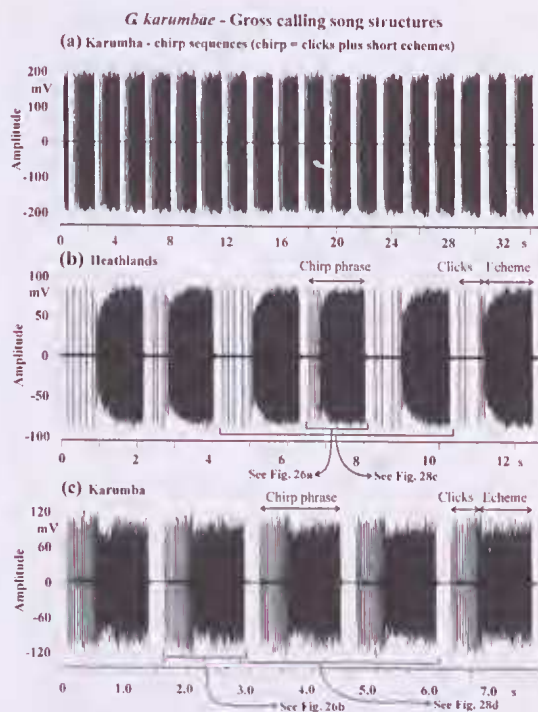


FIG. 25. *Graminitigrina karumbae* sp. nov. Waveform plots of calling songs, showing, (a), gross temporal structures of the chirp phrases, each chirp consisting of initial click sequences followed by the short chirp echeme; (b-c), clicks and their coalescence into the short chirp echemes. (a, c), Karumba, southeastern Gulf of Carpentaria; (b), Heathlands, northern Cape York Peninsula. All based on container recordings, (a, c), unfiltered; (b), filtered (IIR) to 0.5 kHz.

Each macrosyllable is further resolved into two syllables, each with typically 3-4 hemisyllables (noting that the precise delineation of individual hemisyllables becomes less certain within the echemes). Macrosyllable lengths vary between 7.5-11.9 ms, similar to and sometimes shorter than those of the clicks. Syllable and hemisyllable lengths are 3.7-5.7 and 0.95-1.6 ms, also similar to those in the click phases. Although

not shown, detailed pulse measurements made in time expanded waveform plots within individual macrosyllables show frequency ranges between 8200-15800 Hz, and rapid alterations of frequencies on time scales varying between 0.1-1.2 ms, similar to the click macrosyllables, and similarly implying rapid changes in the sound

G. karumbae - Click and echeme macrosyllable structures within chirps

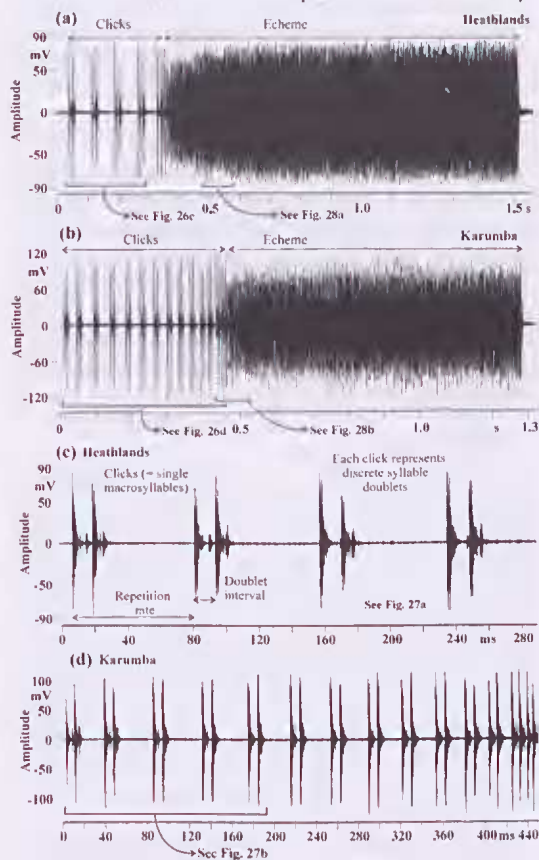


FIG. 26. *Graminitigrina karumbae* sp. nov.. Waveform plots of calling songs showing, (a-b), time expanded plots of the clicks and their progressive coalescence into short chirp echemes; (c-d), higher resolution time expanded waveform plots illustrating more detail of the structures of the clicks. Each click is interpreted as a single macrosyllable made up of two clearly defined high amplitude syllables (syllable pairs). (e) shows the definition of the doublet intervals and repetition length (rate s^{-1}). (a, c), Heathlands, northern Cape York Peninsula; (b, d), Karumba, southeastern Gulf of Carpentaria. Plots based on container recordings, (b, d), unfiltered; (a, c), filtered (IIR) to 0.5 kHz.

G. karumbae - Click macrosyllable structures

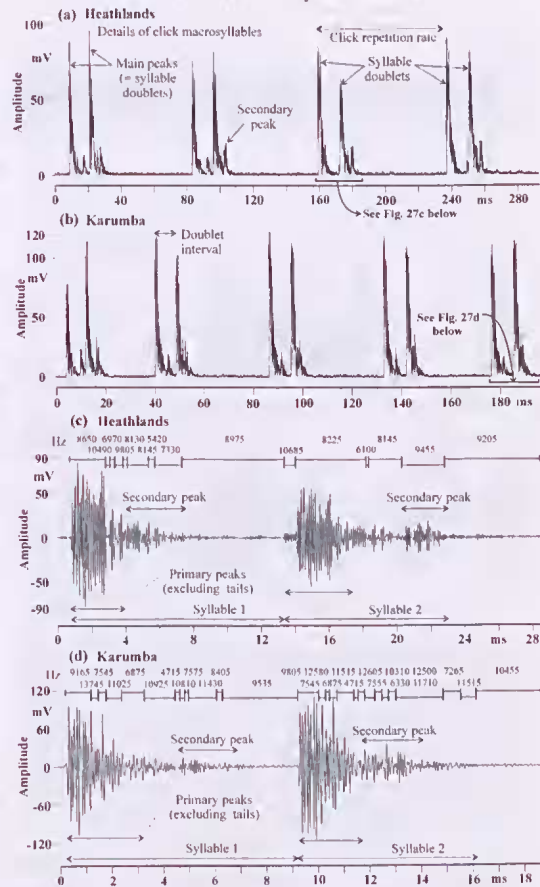


FIG. 27. *Graminitigrina karumbae* sp. nov. Detailed time expanded envelope curves (a-b) and high resolution waveform plots (c-d) of clicks within calling songs. (a-b) illustrate the general form of the syllable pairs. (c-d), shows further details of higher frequency pulse structures within single click macrosyllables, including the resolution of syllable pairs into the higher amplitude 'primary' peaks and weaker secondary peaks, together with the measured sequential frequency changes occurring during the emission of each click, based on pulse counts within the waveform plots (tabulated above each plot). (a, c), Heathlands, northern Cape York Peninsula; (b, d), Karumba, southeastern Gulf of Carpentaria. Plots based on container recordings, (b, d), unfiltered; (a, c), filtered (IIR) to 0.5 kHz.

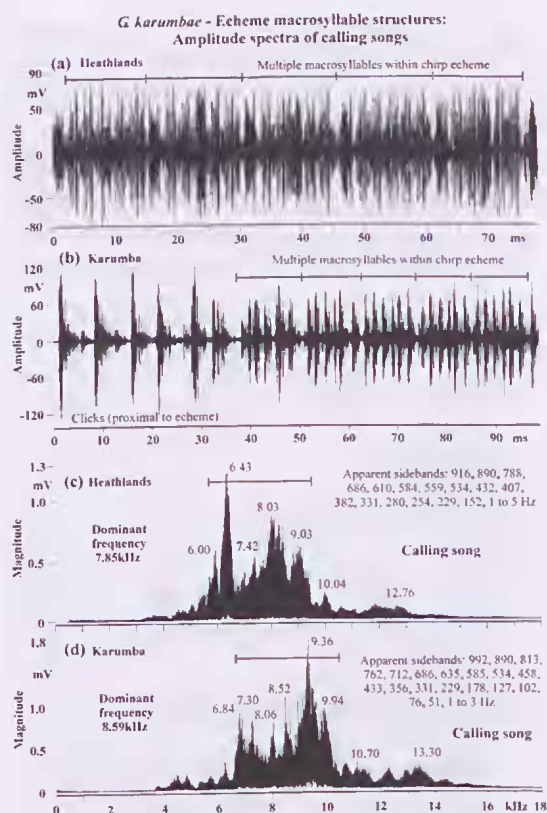


FIG. 28. *Graminitigrina karumbae* sp. nov. Calling song waveform plots showing further details of (a), coalesced multiple macrosyllables within short chirp echeme, the limits of each macrosyllable shown on the accompanying bars (see Fig. 26a for detailed location of plot); (b), transition from discrete syllable doublets (macrosyllables) of the clicks to the coalesced macrosyllables of the following echeme (see fig. 26b for locations of plot); (c-d), Amplitude spectra of the calling songs (see Fig. 25b, c for locations of these spectra). Frequencies of the main peaks are labeled, and the apparent sidebands, measured from the spectra, are tabulated. Horizontal bars indicate the high amplitude segment of each spectrum used to estimate the dominant frequency of each song. (a, c), Heathlands, northern Cape York Peninsula; (b, d), Karumba, southeastern Gulf of Carpentaria. Plot based on container recordings, (b, d), unfiltered; (a, c), filtered (IIR) to 0.5 kHz.

radiating structures (e.g. Fonseca and Popov, 1994). The critical aspect is that the various syllable, macrosyllable and hemisyllable structures, and the overall temporal structures of the chirp phrases, are very close to the calling songs from the Bowen locality.

(iii) *Song frequencies.* (Fig. 23a, b) Amplitude spectra exhibit a series of broad and complex peaks, which tend to define frequency bands between 10.0-10.8, 11.1-11.5, 11.7-12.3, 12.4-13.7, 13.8-14.8 and 15-17 kHz. Dominant frequencies are estimated to be 14.2 and 13.1 kHz (58km SE of Mt Surprise and from Croydon, respectively), very similar to those from Bowen (Fig. 23a). The breadth and complexity of the peaks is again attributed to sets of sideband spectra (details listed in Fig. 23a, b) based on measurements of the spectra. The lower frequency sidebands, below about 0.5 kHz, are reasonably consistent between the three sets of spectra shown in Fig. 23. The broader peak groupings referred to above feasibly result from sets of sidebands at higher frequencies extending from about 0.6 to 1.2 kHz (~1.7 to 0.8 ms), approximately the time domains represented by the complex hemisyllable structures. Macrosyllable and syllable repetition rates lie in the general ranges of 80-135 and 160-270 Hz, while ehrip repetition rates (Table 2) lie between 0.5 to 2.4 Hz. These amplitude modulations evidently span much of the observed sideband frequency ranges.

1C. Short Song

Einasleigh River crossing (35km W. of Mt Surprise), and 11.7km SE of 'The Lynd' Highway Junction (Fig. 16a-e; Fig. 24a, b): The overall chirp structures of these songs differ in detail from the calling songs in the general paucity, usually absence, of precursor clicks, together with the short and erratic timings of the chirp sequence emissions. As noted, these songs were observed in very low density populations. Echeme structures comprise coalesced macrosyllables whose lengths tend to be slightly longer than observed in the calling songs, as are syllable lengths (Table 2).

The structures of the macrosyllables, syllables and hemisyllables are closely comparable to those in calling songs, again with two syllables per macrosyllable. Time expanded waveform plots (not shown) again indicate, as previously, that higher amplitude hemisyllable phases tend to have relatively higher frequencies while the low amplitude phases have both lower and higher frequencies. Rapid temporal frequency changes are characteristic, as in the calling song.

Amplitude spectra (Fig. 24a, b) show both similarities and differences from the calling songs (Fig. 23). The dominant frequencies derived from the spectra lie between 14.0 to 14.6 kHz, slightly higher than the calling songs, but the

most significant differences are seen in the wider frequency range of the stronger frequency peaks, which extend to a low of 4.9 kHz ('Lynd' junction. song) and as high as 17.4-17.5 kHz. Such wide frequency ranges would seem to enhance signal transfer relative to the calling song, perhaps a response to the low densities of these particular cicada populations. The peaks are relatively broad due to the abundant sideband line spectra. The measured sidebands, tabulated within each spectrum (Fig. 24a, b), are comparable to those measured in the calling song spectra (Fig. 23), consistent with the similar amplitude modulations and syllable structures (Table 2).

1D. Alarm (Stress) Song

58km SE of Mt Surprise and Flagstaff Hill, Bowen (Figs 16d; 21, 22a, b): Recordings at both localities were made at a time when the insects were relatively newly emerged and abundant. The song is an aurally monotonous 'buzz', lasting at least five minutes without break. It consists of randomly arranged clicks (single macrosyllables) and short echemes comprising the coalescence of between 2-5 macrosyllables (Figs 16d; 22a, b). The individual macrosyllables comprise two syllables, each with initial hemisyllable doublets. A 'doublet interval' is defined as the interval between the initial peaks in each doublet (Fig. 21c, d). These doublets are thought to represent the alternate (delayed) buckling of each timbal, with time delays of ~0.5-0.7 ms. Nevertheless, the time expanded envelope curves of the two songs (Fig. 21c, d) do differ with respect to the presence of one or two strong peaks at the end of each macrosyllable, these differences consistent throughout each of the respective recorded songs. Macrosyllable lengths range, for the data sets from 58km SE of Mt Surprise and Flagstaff Hill, Bowen, respectively, between 9.1-9.9 ms and 10.6-11.0 ms (clicks) and 8.8-9.8 ms and 10.7-11.4 ms (short echemes), similar to the values found for the calling songs, and also as observed for the syllables and hemisyllables between the two song types. The data suggest no significant compression of syllables during macrosyllable coalescence into the short echemes, while the macrosyllables in the echemes show comparable syllable-hemisyllable structures as observed in the single click macrosyllables.

The detailed waveform plot shown (Fig. 21b) illustrates the relatively high frequencies within both the higher and lower amplitude hemisyllable phases, between 10870-16305 Hz. Frequency changes, between this frequency range, occur

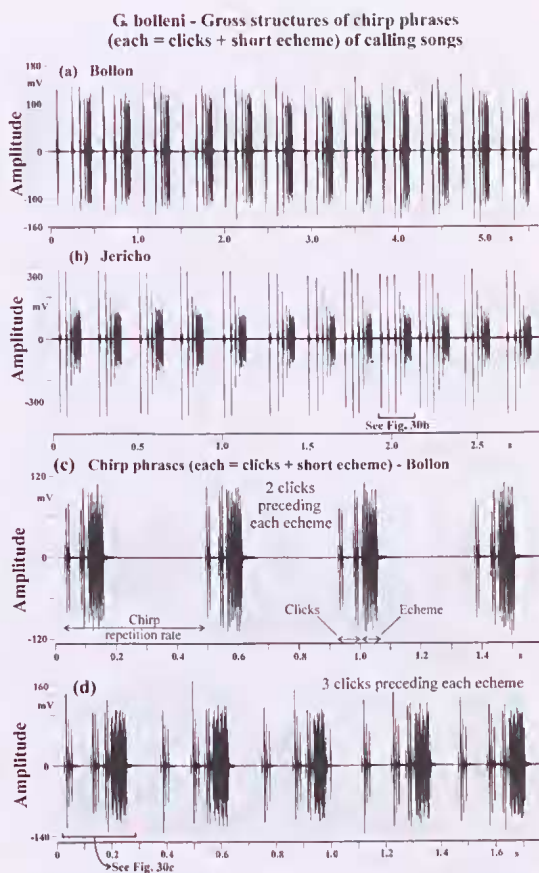


FIG. 29. *Graminitigrina bolloni* sp. nov. (a), waveform plot of calling song from Bollon, S. Queensland, showing repetitive chirp phrases, each comprising a series of initial clicks followed by a short echeme; (b), A comparable plot of a song from near Jericho, central Queensland, showing the repetitive chirp phrases. Note the more sharply defined clicks and lower amplitude short echemes; (c, d), more detailed waveform plots from Bollon showing two (c) and three (d) clicks preceding each echeme, illustrating the variable structure of the chirp phrases. The number of pre-echeme clicks varies between two and seven. The chirp repetition length (rate s^{-1}) definition is also shown in (c). (a), (c), (d), unfiltered container recordings; (b), parabola field recording (L.W. Popple), filtered (IIR) to 2 kHz.

on time domain scales of between 0.2-3 ms. The amplitude spectra of alarm songs from two localities (Fig. 24c, d) are more symmetrical (compared to the calling songs; Fig. 23), with significantly less clearly defined satellite higher or lower frequency peaks than seen in the calling and short song spectra. Complex sidebands are

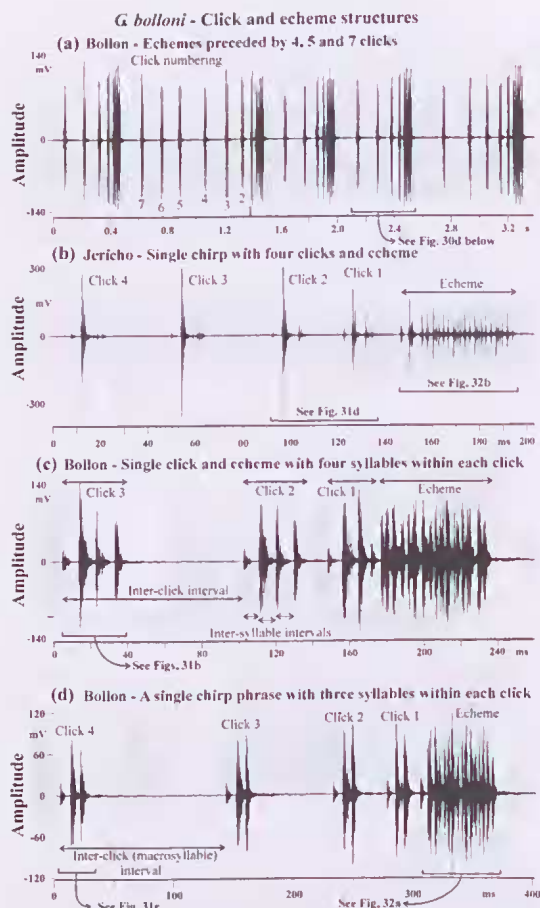


FIG. 30. *Graminitigrina bolloni* sp. nov. Calling song waveform plots; (a), chirp phrases with 4, 5 and 7 clicks preceding the echemes (Bollon song). The reference numbering system used to describe the individual clicks is shown; (b), expanded waveform plot of a single chirp with 4 preceding clicks followed by the short echeme, from near Jericho, central Queensland. Compare the clicks with those from the Bollon songs below and in Fig. 31a; (c), time expanded waveform plot of a 3 click chirp phrase showing in more detail the structure of the individual clicks, each consisting of four syllables, and the following short echeme (see Fig. 29d for location of the plot); (d), corresponding waveform plot of a 4 click chirp phrase, each click with three syllables. (a), (b), (d), unfiltered container recordings from Bollon; (b), parabola field recording, filtered (IIR) to 2 kHz (L.W. Popple).

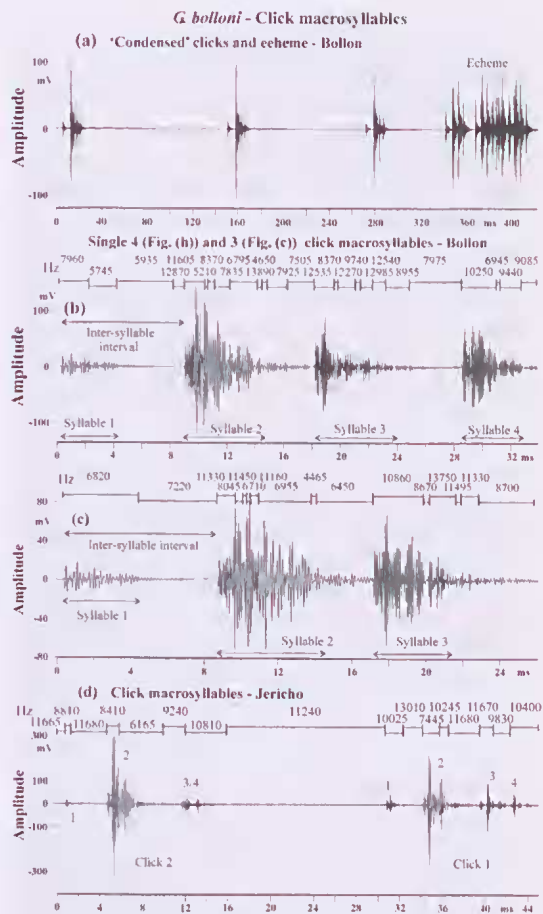


FIG. 31. *Graminitigrina bolloni* sp. nov. Calling song waveform plots; (a), expanded waveform plot of a single chirp phrase from a Bollon song illustrating a less common condensed (compressed) click structure, comparable to those of the Jericho songs; (b), higher resolution time expanded waveform plot of a single 4 syllable click (see Fig. 30c) of a Bollon song showing the measured sequential frequency changes accompanying click emission (tabulated above the plot) and the detailed higher frequency pulse structures within the syllables; (c), higher resolution time expanded waveform plot (Bollon) of a 3 syllable click (see Fig. 30d) showing the measured sequential changes in frequency accompanying click emission (tabulated above the plot) and the detailed higher frequency pulse structures within the syllables; (d), expanded waveform plot of clicks 1 and 2 within a chirp phrase from the Jericho song (see Fig. 30b), showing the gross frequency changes through the click syllables (tabulated above plot). Numbers 1-4 refer to the syllable reference numbering used. (a-c), unfiltered container recordings; (d), parabola field recording, filtered (IIR) to 2 kHz (L.W. Popple).

nevertheless clearly evident. The inferred dominant frequencies overlap those of the calling songs.

1E. Ratchet Song

Bowen locality. This comprises (Figs 15a, b; 22c, d) a regular sequence of single clicks (macrosyllables) emitted at a relatively constant repetition rate within a given song sequence, this being 27 Hz (37 ± 6 ms) in the example shown. Interestingly, the click repetition rates are very similar to those for the ratchet song of *G. triodiae* (see below). Each macrosyllable (e.g. Fig. 22d) has a structure that is comparable to those of the single click macrosyllables of the calling songs (Fig. 19c, d) and stress songs (Fig. 21b-d). Each consists of two coalesced syllables with doublet intervals, as well as macrosyllable, syllable and hemisyllable properties close to those of the stress songs (Table 2).

The amplitude spectra (not shown) exhibit a blurring of the distinct frequency maxima seen in the calling and stress songs, with a broader continuity of emitted frequencies between 9 to 16 kHz and dominant frequency of 12.3 kHz, in many respects similar to the alarm song (Fig. 24c, d), but not quite as smoothly continuous in their frequency distribution. The amplitude spectra exhibit a clearly dominant sideband corresponding to the click repetition rate.

2. *G. karumbae*

2A. Calling song

Karumba and Heatlands localities. (Figs 25-28; Table 3). This song is superficially similar to that of *G. bowensis*, consisting of repeated chirp phrases (Fig. 25a) with no extended echeme phase observed. A ratchet song is emitted in the field (but has not been electronically recorded) at the end of a given song phase, followed by flight to new song post, as described for *G. bowensis*. Each chirp phrase consists of a sequence of clicks which merge into the short chirp echeme (Figs 25b, c; 26a, b). Click numbers vary between 2-13, similar to *G. bowensis*. Chirp lengths vary between 0.85-1.5 s, with repetition rates of 0.33 - 0.66 s⁻¹, both parameters differing from *G. bowensis*. The repetition rates progressively increase during emission. It is in the detailed chirp structures and frequencies, however, that the songs of *G. karumbae* and *G. bowensis* differ so markedly.

(i) **Clicks.** Time expanded envelope and waveform curves of individual click macrosyllables

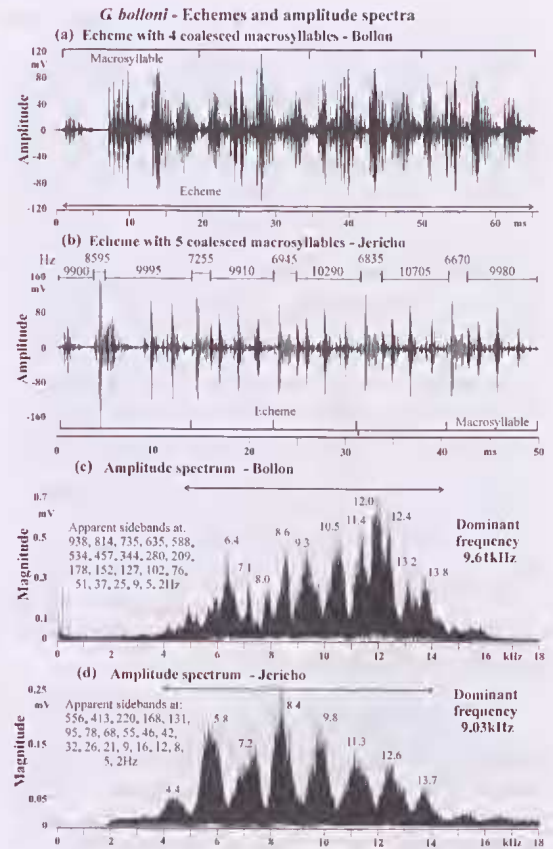


FIG. 32. *Graminitigrina bolloni* sp. nov. Higher resolution time expanded waveform plots of calling songs of; (a), the short echeme from a single chirp phrase (see Fig. 30d) from a Bollon song, comprised of 4 coalesced macrosyllables (their limits shown by the bars); (b), short echeme from chirp phrase of the Jericho song (see Fig. 30b) showing five coalesced macrosyllables (limits marked by the bars). Gross frequency changes occurring through the echeme emission are illustrated, in particular noting the lower frequencies occurring within the initial syllables of each macrosyllable, these frequencies reducing progressively during echeme progression; (c), (d), amplitude spectra of the calling songs from Bollon. and Jericho, respectively. Frequencies of the main peaks are labeled, and the apparent sidebands, measured from the spectra, are tabulated. Horizontal bars mark the higher amplitude segments used to estimate the dominant frequencies of each song. (a), (c), unfiltered container recordings; (b), (d), parabola field recording, filtered (11R) to 2 kHz (L.W. Popple).

(Figs 26c, d; 27) show that each macrosyllable consists of pairs of clearly developed syllables, each of which decays exponentially and is followed by small but distinct secondary peaks occurring

within the decaying peak tails (Fig. 27). These are termed here 'syllable doublets' rather than diplosyllables, in order to avoid obscuring certain similarities in syllable structures to those of the *G. bowensis* song. The detailed structures of the main syllable peaks in each doublet are very similar (e.g. Fig. 27c, d), suggesting the doublets result from alternate and abrupt contractions of each timbal (i.e. long ribs 'locked' as a single unit). The smaller secondary peaks may therefore represent the successive relaxation phase of each timbal, which if correct, occurs approximately 3 to 6 ms after the initiation of the preceding main syllable peaks. Mean spacing between each set of doublet syllables (excluding tails) are 9.0 ms (Karumba) and 12.5 ms (Heathlands), these differing markedly from the equivalent doublets in the *G. bowensis* songs (3.0-5.2 ms; Tables 2 and 3). The spacings between the sets of doublets reduce to 4-8 ms in proximity to the following short echeme. Macrosyllable lengths are 11.5-14.2 ms (Karumba) and 18.0-21.7 ms (Heathlands), which compare with 8.9-14.4 ms for *G. bowensis* songs (Tables 2, 3).

Pulse measurements resolved in the expanded waveform plots (Figs 27c, d) indicate frequencies of between 5420-10685 Hz (Heathlands) and 4715-12605 Hz (Karumba), clearly lower than observed for *G. bowensis* songs. Rapid frequency oscillations, however, again occur on time scales between 0.1-6 ms. The highest amplitude syllable segments are generally characterised by the higher frequencies.

(ii) *Short echemes*. As shown in Figs 25b, c; 26a, b; 28b, the chirps merge, with compression of the macrosyllables, into the following echeme which comprises sequences of coalesced macrosyllables. Mean macrosyllable lengths are 11.5 (Karumba) and 15.2 ms (Heathlands), longer than in the corresponding *G. bowensis* short echeme phrases, but shorter than observed in the associated clicks.

Although the macrosyllables are readily discernable within the echemes (Fig. 28a, b), detailed syllable structures are more complex than those in the click macrosyllables. For example, the well defined click syllable doublets (e.g. Fig. 27c, d) merge into echeme macrosyllables, each with initially 5-6 high amplitude pulse phrases (Fig. 28b), but later in the echeme, these tend to further coalesce and blur individual syllable identities (e.g. Fig. 28a). A possible explanation is increasing frequency of timbal contractions during echeme emission, the individual timbals

becoming less rigid, allowing sequential (rather than locked) buckling of the ribs. Detailed time expanded waveform plots (not shown) of single macrosyllables from within echemes exhibit rapid alternation of higher and lower frequency domains comparable to those seen in the click phases (Fig. 27c, d).

(iii) *Song frequencies*. Amplitude spectra (e.g. Fig. 28c, d) exhibit a complex series of broad peaks, the strongest peaks defining a frequency window between 5.3 to 12.5 kHz (four separate insects). These frequencies are consistent with those measured on waveform plots (e.g. Fig. 27c, d), the estimated dominant frequencies ranging between 8.5-9.1 kHz (Karumba) and 7.85 kHz (Heathlands). Amplitude spectra of the click phrases alone (not shown) exhibit a distinct enhancement of both the lower and higher frequency peaks. Most significantly, the *G. karumbae* frequencies are markedly lower than those observed for *G. bowensis* calling songs.

3. *G. holloni*

3A. Calling Song

Bollon locality. (Figs 29-32; Table 4) These typically start with a short buzz (not recorded), followed by a characteristic rapid, sharp chirping song (Fig. 29a), aurally resembling a rattling sound, emitted whilst sitting in grass. This is followed by flight to a new singing position accompanied by a 'ratchet song' (not recorded), thus exhibiting the classic "sing and fly" behaviour. The chirping song consists of short, rapidly repeated chirp phrases, each consisting of a set of short clicks followed by a short echeme of 54-90 ms (Figs 29c, d; 30a). The number of clicks varies from 2 to 7, most usually between 2 to 5. The repetition rates of the chirp phrases vary according to the number of preceding elicks and range from 1.8 s⁻¹ (4 clicks) up to 3.3 s⁻¹ (2 clicks; Table 4). The following descriptions deal with the structures and frequencies of the click and echeme phrases separately.

(i) *Clicks*. (Figs 29c, d; 30a-d; Table 4) These occur as sets of syllables, grouped into macrosyllables, which most commonly comprise sets of either triple (Figs 30d, 31c) or quadruple (Figs 30c, 31b) syllables. The sets of triplet syllables occur where >3 elicks precede each echeme, while the macrosyllables with quadruplet syllables occur where ≤3 clicks precede each echeme; in the latter cases, the final macrosyllable reverts to the triplet syllable arrangement. Click repetition rates

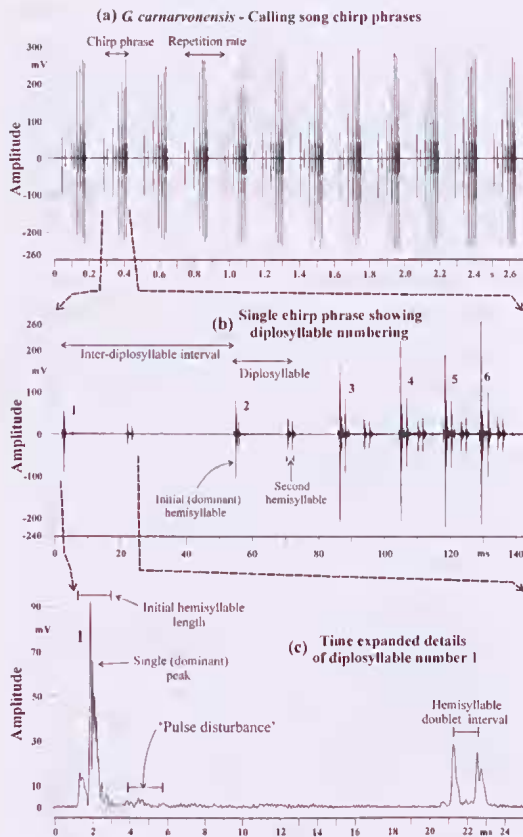


FIG. 33. *Graminitigrina carnavonensis* sp. nov. (a), waveform plot of 12 phrases (chirps) from a calling song, each comprising 12 clicks, each pair of clicks here termed diplosyllables. Definitions of the chirp lengths and repetition lengths (rates s^{-1}) are shown; (b), time expanded diplosyllables from one phrase showing alternation of high and low amplitude hemisyllables, and numbering system used to reference individual diplosyllables. This plot also shows that the low amplitude hemisyllables are all doublets, as are most of the high amplitude hemisyllables. The high amplitude hemisyllable in diplosyllables 1 is a single syllable; (c), higher resolution envelope curve showing time expanded detail of diplosyllable 1 and the 'pulse disturbance' following the emission of the initial hemisyllable. The definition of the hemisyllable doublet intervals is shown. Based on field recording (open net cage), with parabola, from Mt Moffat Section of Carnarvon National Park (4.3km N. of entrance) filtered (IIR) to 0.2 kHz.

increase towards each following short echeme. For the earlier click macrosyllables in a sequence (click numbers >3 ; see Fig. 30a for the numbering sequence used for the clicks), excluding the final 3 before the short echeme, the repetition rate ranges

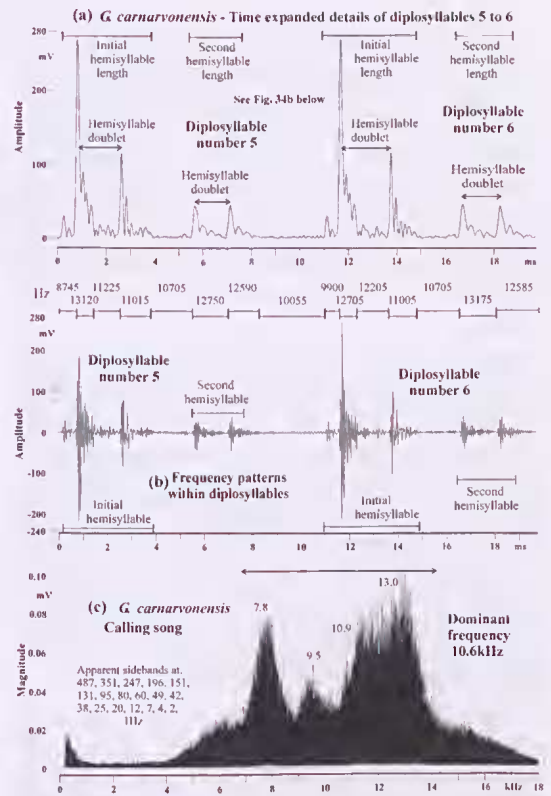


FIG. 34. *Graminitigrina carnavonensis* sp. nov. Calling song; (a), higher resolution time expanded envelope curve showing detailed structures of diplosyllables 5 and 6, and definitions of hemisyllable doublets and lengths; (b), corresponding waveform plot showing details of the higher frequency carrier pulses, together with the gross sequential changes of frequency occurring during each hemisyllable emission (based on detailed pulse measurements in this plot); (c), amplitude spectrum of the calling song, based on analyses of an extended set (29 seconds) of sequential chirp phrases. Frequencies of the main peaks are labeled, and the apparent sidebands, measured from the spectra, are tabulated. The horizontal bar marks the higher amplitude segment used to estimate the dominant frequency of the song. Recording details as in Fig. 33.

between 8.1–5.2 Hz (mean 6.4 Hz), equivalent to 124–191 ms. Between click numbers 3 and 2, the rate increases to 11.6–8.9 Hz (86–113 ms), which further increases to 23–15 Hz (43–67 ms) between click numbers 1 and 2, and to 43–26 Hz (23–38 ms) between the final click (number 1) and the start of the following short echeme. The click macrosyllable lengths range between 19.9–23.7 ms (triplets) to 26.1–33.0 ms (quadruplets).

Each click macrosyllable starts with a relatively low amplitude, abruptly initiated syllable (Fig. 31b, c), the following syllables having markedly increased amplitudes. Mean syllable lengths vary between 4.4-6.0 ms, the shortest being the initial syllable and also the final syllable in the quadruplet macrosyllables. Mean syllable repetition rates range between 8.4-10 ms (119-100 Hz). More detailed time expanded plots of the syllables suggest the probable presence of discrete hemisyllables with lengths varying between 0.9-1.2ms.

Measurements of pulses resolved within the time expanded waveform plots of the triplet (Fig. 31c) and quadruplet (Fig. 31b) click macrosyllables show marked and sharply defined variations of frequencies between approximately 6-14 kHz. The higher frequencies occur consistently within the initial segments of syllables 2, 3 and 4, but also in very short bursts (~1 ms) in the decaying phase of especially syllable 3. Syllable 1 consistently exhibits lower frequencies of <8 kHz. Syllables 2-4 show an alternation of higher and lower frequencies on time scales as short as 0.3 ms.

Certain click macrosyllable structures are relatively atypical, comprising effectively condensed short syllables (compressed syllables), shown by clicks 2-4 in Fig. 31a. The final click (number 1) in the illustrated sequence comprises a normal macrosyllable structure with four distinct syllables. Each click macrosyllable is nevertheless initiated by a sharp, low amplitude syllable, as in the normal clicks. Macrosyllable lengths range between 14-17 ms in these compressed clicks, in fact slightly longer than those of the normal click macrosyllables.

(ii) *Short Echemes.* (Fig. 30c, d) These represent the coalescence of multiple macrosyllables, which individually comprise the clicks as described above. Each macrosyllable in the short echemes can be resolved into four distinct syllables, each with poorly resolved component hemisyllables. The echemes typically comprise between 3-5, less often to 8, macrosyllables. Syllable lengths range between 2.4-6.0 ms (mean 3.8 ms), tending to be slightly shorter than those measured in the click macrosyllables, indicating syllable compression. The initial macrosyllable in each echeme is the longest. Hemisyllable lengths, when resolvable, range between 0.2-1.0 ms, also shorter than those in the clicks. Pulse measurements in time expanded waveform plots indicate rapid frequency changes within the macrosyllables (not shown), as also seen in the

click macrosyllables. The measured frequencies determined by the pulse counts ranged between approximately 6 to 14 kHz, also consistent with the click macrosyllable data (above). These frequency changes are short and abrupt, occurring on time scales of 0.2-1.1 ms, presumably resulting from abdominal movements during singing and the corresponding changes in sound radiation and transmission mechanisms.

(iii) *Song frequencies.* (Fig. 32c) The amplitude spectra of multiple chirp phrases are remarkably complex, with multiple strong frequency peaks. In the spectrum shown (Fig. 32c), the highest amplitude peak occurs at 12 kHz, but strong ancillary peaks occur at 6.4, 8.6, 9.3, 10.5, 11.4 and 12.4 kHz, with further significant peaks at 5.0, 6.0, 7.1, 8.0, 13.2, 13.8, and 14.9 kHz. The highest amplitude peaks vary between 10-12 kHz in the spectra from different insects, although the multiple frequency peaks present exhibit comparable frequencies. The mean dominant frequency is estimated to be 9.6 kHz (Table 4) from recordings of four separate insects. A conspicuous additional feature is the array of line spectra producing the broadening of the frequency peaks. Measurements of the line spectra frequencies suggest sidebands extending from 1132 to ~1 Hz (those <1 kHz tabulated in Fig. 32c). The amplitude modulations defined by the syllable and hemisyllable structures (see above) have the potential to account for sidebands in the range between ~125 Hz to ~1.1 kHz, respectively. The measured sidebands of 1042 and 1132 Hz could thus represent the lower frequency components of the hemisyllable modulation patterns. Repetition rates of the chirp phrases (1.8-3.3 Hz), clicks (5-43 Hz), and inter-syllable intervals (7.3-10.2 ms; 98-137 Hz) may account for the observed lower frequency sidebands. The wide range of the amplitude modulations certainly contributes to the complexity of the line spectra. It is possible that some of the line spectra with apparent frequencies between about 300-1000 Hz may represent multiples of the lower frequency sidebands, an artifact of the measurement procedures.

The wide range and widths of the frequency peaks observed in the spectra may be attributable to the existence of different sound radiating structures, each with different properties. This seems to be supported by the rapidly changing frequencies seen in the waveform plots, in which higher frequencies occur in the initial, higher amplitude phases within the syllable (see above). Abdominal movements are suggested

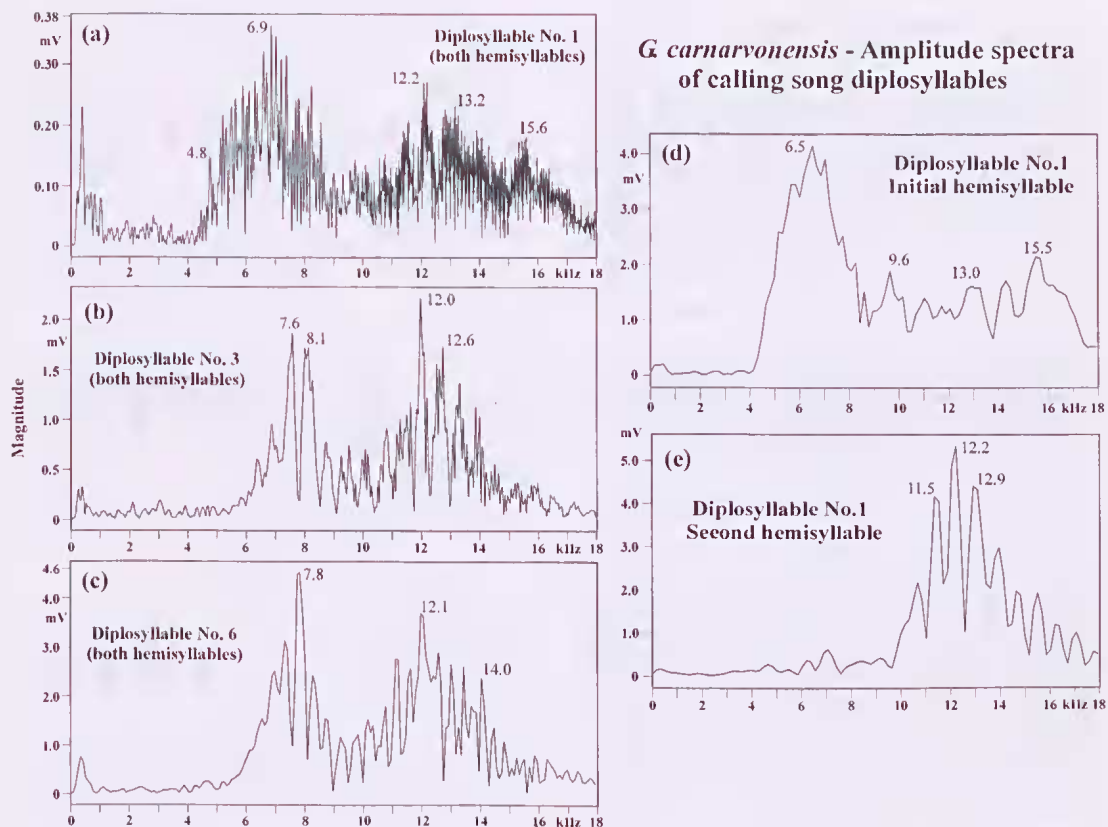


FIG. 35. *Graminitigrina carnarvonensis* sp. nov. Amplitude spectra of, (a-e), individual sets of diplosyllables (numbers 1, 3, and 6) from within a calling song chirp; (d-e), the initial and second hemisyllables within diplosyllable number 1 (see (a)). Frequencies of the main peaks are labeled. Recording details as in Fig. 33.

to modify/activate/deactivate the various sound transmitting organs, which may account for the rapidity of alternation of frequency changes, on the observed time scales as short as 0.2 ms.

Jericho locality. (Figs 29-32; Table 4) The overall temporal structures of the Bollon and Jericho songs are very similar, the latter also comprising a repetitive series of sharp chirp phrases. Each chirp again consists of 3 to 4 short clicks followed by a short echeme (Fig. 29b), although the chirp repetition rate is notably faster than the Bollon songs (Table 4). One significant difference between the two sets of songs is seen in the click structures (compare Figs 30b-d; 31b-d), in which the Jericho clicks are more sharply defined. Each click initiates with a low amplitude syllable, followed by a high amplitude second syllable and low amplitude syllables 3 and/or 4 (Figs 30b, 31d), the latter two syllables often not clearly resolved. Only in click number 1 do syllables 3 and 4 show clear separation and development.

Although differing from the normal Bollon click structures, it has been noted above that compressed click structures are observed in the Bollon songs, although much less frequently (Fig. 31a); these are nevertheless similar to the Jericho click structures. The distinctive Jericho click structures are reflected in shorter echeme macrosyllable lengths, which exhibit more sharply defined and separated syllables (Figs 30b, 32b). The echemes are inferred to result through coalescence of 4 to 5 click macrosyllables, each of which comprises four syllables.

The differing, more compressed click and echeme structures of the Jericho songs are further reflected in shorter inter-click intervals and click and echeme lengths; and in shorter total click lengths, inter-syllable intervals and syllable macrosyllable lengths (Table 4). The amplitude spectra (e.g. Fig. 32d) exhibit very clearly defined, broad and regularly spaced frequency peaks, centered near 4.4, 5.8, 7.2, 8.4, 9.8, 11.3, 12.6 and 13.7 kHz. The

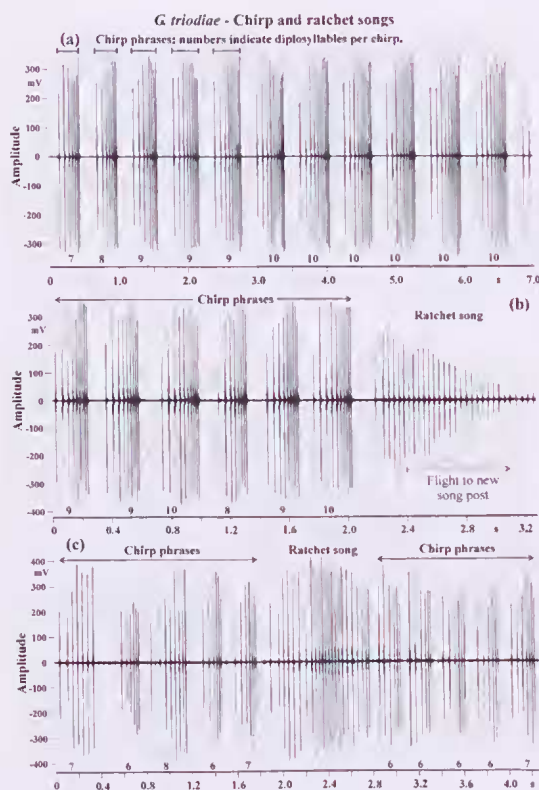


FIG. 36. *Graminitigrina triodiae* sp. nov. Waveform plots of; (a), multiple chirps within calling song, the individual chirps comprising between 7 to 10 diplosyllables; (b), a sequence of chirp phrases (each with 8 to 10 diplosyllables) followed by the ratchet song emitted immediately prior to, and accompanying flight; (c), ratchet song emitted within the normal calling song chirp sequences. Parabola field recordings, filtered (IIR) to 1 kHz, Burra Range section of White Mountain National Park.

separations range between 1.1 to 1.5 kHz, the mean separation being 1.3 kHz, equivalent to 0.77 ms, possibly reflecting hemisyllable structures within the echemes and clicks (although not clearly resolved in the waveform plots). Apparent sidebands are listed in Fig. 32d, showing both similarities and differences with those of the Bollon songs (Fig. 32c). These seem to reflect both the gross song similarities, but also the finer scale pulse structure differences.

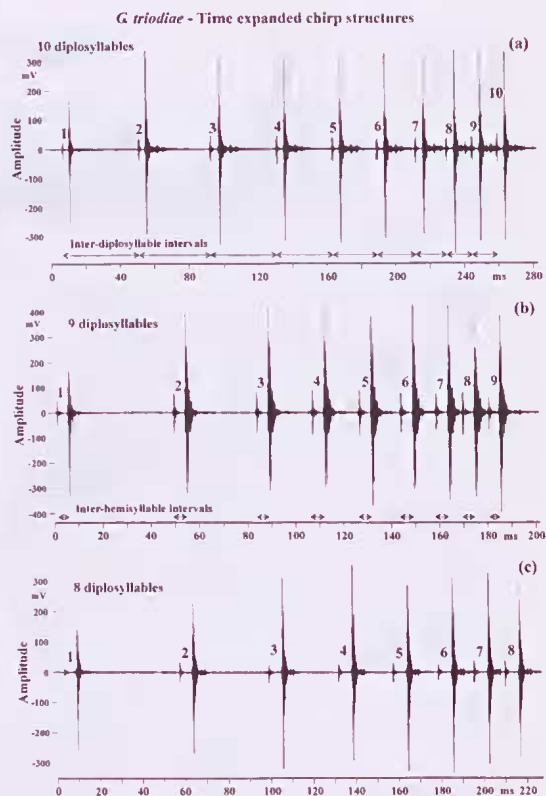


FIG. 37. *Graminitigrina triodiae* sp. nov. Time expanded waveform plots of individual chirp phrases within calling song showing details of diplosyllable structures, and the numbering system used. Number of diplosyllables per chirp vary between (a), 10; (b), 9; (c), 8. Recording details as in Fig. 36.

4. *G. carnarvonensis*

4A. Calling Song

Mt Moffat Section of Carnarvon National Park locality. (Figs 33–35; Table 5) A cryptic and wary species as characteristic of the other *Graminitigrina* species. The song data illustrated are recordings made in an open net cage, in the field in grassland associated with open forest. The song differs substantially from the previous three *Graminitigrina* songs described, consisting of repeated chirp phrases, each consisting of sets of distinct clicks (pulses) which exhibit a distinct pattern of amplitude and temporal patterning (Fig. 33a, b); no extended echeme or ratchet phrases have been observed. The clicks occur in pairs, an initial high amplitude phase followed by a low amplitude phase. These pairs are here termed *diplosyllables*. There are normally 6

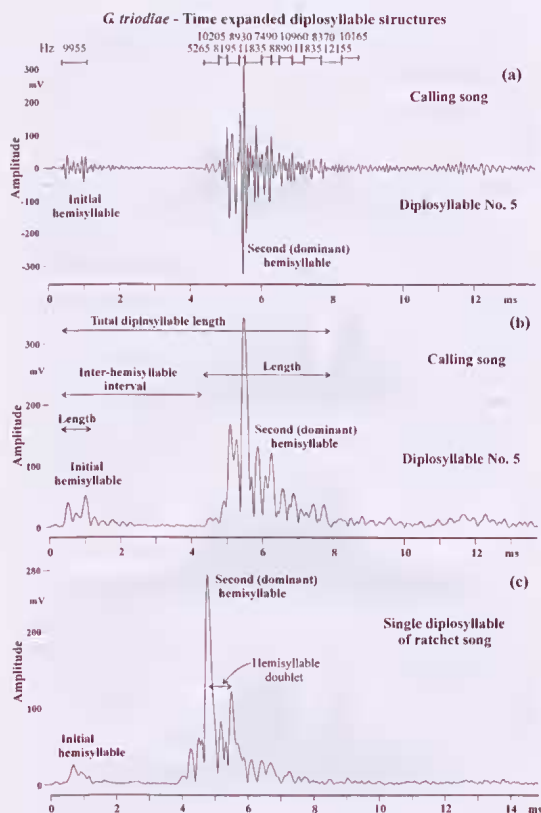


FIG. 38. *Graminitigrina triodiae* sp. nov. (a), high resolution waveform plot showing the rapid frequency changes measured (from the plot) within diplosyllable number 5 of the calling song; (b), corresponding envelope curve, showing definition of parameters and terms used in Table 6; (c), high resolution envelope curve showing details of a single diplosyllable of the ratchet song. Recording details as in Fig. 36.

sets of diplosyllables within each chirp phrase; in one recorded song, however, a small number of chirps possessed 7 sets, and an even smaller number has 5 sets of diplosyllables. The two clicks (pulses) within each diplosyllable are here termed the initial (high amplitude) and the second (low amplitude) hemisyllables, respectively (Fig. 33c). The initial hemisyllable of diplosyllable 1 (numbering shown in Fig. 33b) consists of a single dominant pulse. Diplosyllables 2 and 3 (and 4, 5 in the chirps with 7 diplosyllables) are also single hemisyllables in many recorded chirp phrases. The remaining initial hemisyllables, and all the second hemisyllables occur as clearly defined 'hemisyllable doublets' (e.g. Figs 33c; 34a, b). The initial hemisyllables of diplosyllables 3 to 6 also have higher amplitudes than those of

diplosyllables 1 and 2. The emission rate of the diplosyllables progressively increases during the emission of each phrase (Fig. 33b, Table 5). Chirp phrase lengths range between 120–190 ms, with mean chirp repetition rates of 3.8 Hz (261 ms), these varying between 209–366 ms (2.7–4.8 Hz). Just as the inter-diplosyllable intervals decrease during emission of each chirp phrase, the time intervals between adjacent hemisyllable pairs within each diplosyllable also decrease (Fig. 33b; Table 5).

(i) *Diplosyllable and hemisyllable structures.* A characteristic feature of the initial hemisyllables of all diplosyllables is the presence of a distinct preliminary small pulse emitted approximately 0.6 ms (0.37–0.82 ms) prior to the leading main peak of each hemisyllable (Figs 33b, c; 34a). Small 'pulse disturbances' (in fact, two sets may be present in diplosyllable 3) follow the emission of the single initial hemisyllables of the diplosyllables 1 (± 2 , ± 3). These occur ~2.5–5.6 ms following the preceding initial hemisyllable (up to 9.3 ms in the cases of double 'pulse disturbances' associated with diplosyllable 3). Similar 'pulse disturbances' are not clearly identified following the initial hemisyllables of diplosyllables 4 to 6 (all hemisyllable doublets). The hemisyllables comprising single pulses have lengths (including the tail and preliminary peak) of ~1.7 to 2.0 ms (Table 5); in contrast, the corresponding doublet initial hemisyllables of diplosyllables 2 to 6 (Fig. 34a, b) have lengths between 2.0–3.0 ms, suggesting that the second peak of the doublet represents the appearance of an additional peak. The second hemisyllable doublets of all 6 diplosyllables are similar in structure. In these second hemisyllables, time intervals between the two peaks comprising each hemisyllable doublet range between 0.8–2.0 ms (diplosyllables 4 to 6), 0.9–2.0 ms (diplosyllables 1, 2) and 1.6–2.7 ms (diplosyllable 3; Table 5), each of similar magnitude.

(ii) *Song frequencies.* The amplitude spectrum shown (Fig. 34c) is based on analyses of a sequence of 29 seconds of continuous chirp phrases. It exhibits a complex broadband spectrum extending between approximately 6–14 kHz, with two broad main peaks centered at 7.8 and near 13 kHz, and a smaller peak at 9.5 kHz. The spectrum is bimodal. The breadth and complexity of the spectral peaks is attributed to the extensive sets of sideband line spectra (tabulated in Fig. 34c). The various chirp diplosyllables, and their varying repetition rates, chirp lengths and inter-diplosyllable intervals, result in a wide range of

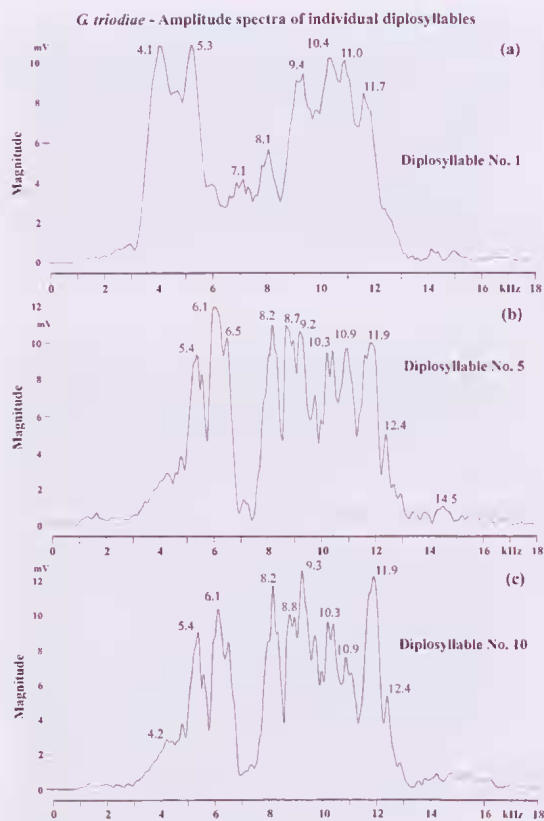


FIG. 39. *Graminitigrina triodiae* sp. nov. Amplitude spectra of individual sets of diplosyllables (numbers 1, 5 and 10) within a single calling song chirp. Frequencies of the main peaks are labeled. Recording details as in Fig. 36.

possible amplitude modulations, listed in part in Table 5. The corresponding frequencies of these amplitude modulations range from ~2.7 to 200 Hz (Table 5) and are represented as sidebands in the amplitude spectra (e.g. Fig. 34c). Added to these are the higher frequency amplitude modulations seen in the detailed hemisyllable structures (Figs 33c, 34a; Table 5), whose numerical values differ through the changing diplosyllables comprising each chirp phrase; these modulations extend to above 450 Hz (Table 5), further emphasising the complexity of this song. The mean dominant frequency of the calling song is estimated to be 10.1 kHz (three separate insects; Table 5).

Frequencies of the carrier wave pulses measured from time expanded waveform plots (e.g. Fig. 34b) are clearly in the range demonstrated by the amplitude spectra (e.g. Figs 34c; 35a-e), ranging between 7865-13120 Hz (initial hemisyllables),

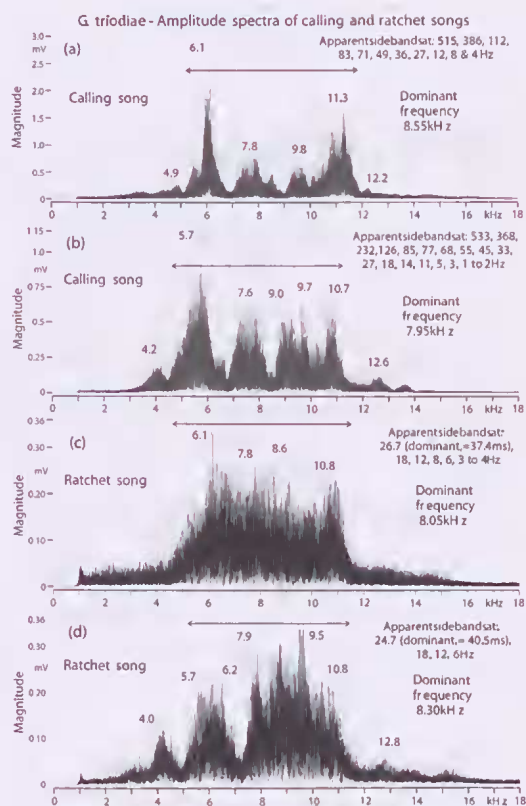


FIG. 40. *Graminitigrina triodiae* sp. nov. Amplitude spectra of, (a-b), sequences of multiple chirps (10 to 11) within calling songs from two separate insects; (c-d), multiple diplosyllables within ratchet songs from two separate insects. Frequencies of the main peaks are labeled together with the apparent sidebands measured from these spectra. Recording details as in Fig. 36.

and 9710-13620 Hz (second hemisyllables), suggesting that the second hemisyllables possesses slightly higher overall frequencies. The 'pulse disturbances' seen within diplosyllables 1 to 3 tend to have frequencies similar to their preceding initial hemisyllables. It is also notable that the initial small pulses occurring at the start of each of the initial hemisyllables have consistently lower frequencies compared with the following the main segments of these hemisyllables. The differing frequency structures within the various diplosyllables are further illustrated in Fig. 35a-e, which compare the amplitude spectra of diplosyllables 1, 3, and 6 from a selected single chirp phrase. The general form of the spectra are modified by the progressively reducing spacings between the initial and second hemisyllables in diplosyllables 1 to 6. Nevertheless, each

clearly shows the bimodal frequency character of the spectra. From these, it is evident that in diplosyllable 1 a relatively greater concentration of frequency peaks below about 9 kHz is present, this contrasting with the spectra of diplosyllables 3 and 6. The relative frequency distributions within the initial and second hemisyllables of diplosyllable 1 (Fig. 35d, e) show that it is actually the initial hemisyllable (high amplitude) that is characterised by the lower frequencies (~5-8 kHz), the second hemisyllable exhibiting clearly higher frequencies between approximately 11-13 kHz. The remaining diplosyllables, however, do not show such marked differences between the overall frequency structures of the two hemisyllables (Fig. 34b), although noting (as above), the short lower frequency segments at the start of each initial hemisyllable.

4B. Interpretation

The song of *G. carnarvonensis* is distinct from the three species previously described, although resembling that of *G. triodiae* (see below). The timbal structure (Fig. 11) of *G. carnarvonensis* shows four very pronounced long ribs, with ribs 1-3 clearly fused ventrally and dorsally, while rib 4 is not fused ventrally. Three short ribs are present. Several possibilities exist for relating the observed song structures to timbal morphology. These include: (a) The second hemisyllables (all doublet pulses) represent the 'clicking back' during timbal relaxation, the high amplitude initial hemisyllables representing the initial inward buckling. This explanation may be appropriate where both the high and low amplitude syllables are clearly doublets (diplosyllables 4 to 6, ± 2 , ± 3), but seems to require that the hemisyllable doublets result from the clicking of ribs 1-3 as a 'locked' unit, followed by rib 4, in both 'inward' and 'outward' movements. The initial single 'pulse' hemisyllables could represent the inward clicks (and resulting sound radiation) under higher impedance conditions, which decrease during the emission of each chirp phrase. This may also relate to the 'pulse disturbances' seen to follow these single initial hemisyllables, and also the wider separation of the following second hemisyllable doublets. (b) A second possible interpretation is that each initial hemisyllable represents a complete 'in-out' timbal movement of the 'locked' ribs 1 to 3. The low amplitude second hemisyllable doublets may therefore represent the 'in-out' movement of long rib 4, although it is not clear how this could account for the single initial hemisyllables

of diplosyllables 1, ± 2 , ± 3 . However, unlike the initial hemisyllables of diplosyllables 4 to 6, diplosyllables 1 to 3 are followed, after approximately 2.5-5.6 ms, by a short 'pulse disturbance', which might feasibly represent the strongly damped relaxation 'click' of ribs 1-3.

5. *G. triodiae*

5A. Calling Song

Burra Range section of White Mountain National Park locality. (Figs 36, 37) The calling song has similarity to that of *G. carnarvonensis*, again consisting of repeated chirp phrases, each comprising discrete diplosyllables which most commonly vary between 7 to 10, less often 6 to 11, in number (Figs 36, 37; Table 6). Chirp phrase lengths range between approximately 148-281 ms (field recordings), and 255-436 ms (container recordings), the lengths predictably correlating with the number of diplosyllables present. Each diplosyllable comprises an initial low amplitude hemisyllable, followed by a high amplitude (dominant) second hemisyllable (Figs 37, 38), the reverse of that seen in the *G. carnarvonensis* calling song. Each chirp phrase is characterised by a progressive increase in diplosyllable emission rate from start to finish, as in *G. carnarvonensis* (Figs 36, 37; Table 6), ranging from near 18 Hz to approximately 70 to 80 Hz at the end (Table 6). Repetition rates of the chirp phrases vary between 2.2-4.3 Hz for field recordings, and are significantly slower at 1.3-1.9 Hz for container recordings; the differences are attributed to the observation that all specimens recorded in the field were singing in direct sunshine.

As observed in some other *Graminitigrina* species, an additional 'ratchet' song is emitted almost invariably at the end of a calling song sequence, when the cicada is about to fly to, and during actual flight, to a new singing perch (Fig. 36b). Rarely the 'ratchet' song occurs within the calling song phase (Fig. 36c), seeming to accompany reduced diplosyllable numbers in associated chirp phrases. The 'ratchet' song is characterised by a series of discrete diplosyllables showing, within a given song, a relatively consistent repetition rate, and when at the end of a calling song, reduced amplitude accompanying the flight of the insect away from its singing post.

(i) *Diplosyllable structures.* The distinctive feature is the presence of the low amplitude of the initial hemisyllable, followed by the dominant (high

amplitude) second hemisyllable. Notwithstanding the increasing repetition rate of the diplosyllables in each chirp, the inter-hemisyllable intervals (Fig. 38b) are constant (mean 4.1 ms; Table 6), with no systematic variation evident within each diplosyllable. The lengths of both the initial and second hemisyllables are also relatively constant (means of 0.93 and 3.5 ms, respectively), while pulse structures with both types of hemisyllables through a given chirp phrase are very similar (e.g. Fig. 37). The consistency of these parameters indicates that each diplosyllable likely results from the same sound producing mechanism. As shown in Fig. 38a, b, the dominant second hemisyllable does not initiate instantly, but builds to a maximum over approximately 1 ms, and decays along a broadly logarithmic curve over approximately 2 to 2.5 ms. The actual point of initiation of these hemisyllables are marked by a very low amplitude 'disturbance' (shown in Fig. 38a, b).

(ii) *Song frequencies.* As observed in the previously described songs of *Graminitigrina* species, measurements of pulses made on detailed waveform plots (e.g. Fig. 38a) reveal rapid and marked changes of pulse frequencies (5265-12155 Hz), even within individual second hemisyllables, on time scales between 0.2-0.6 ms. Figure 38a also indicates that the frequencies extend to both lower and higher values than observed in the smaller initial hemisyllables. Comparison of detailed waveform plots of different diplosyllables from within a given chirp phrase suggests some subtle frequency differences between the initial diplosyllable (number 1; diplosyllable numbering shown in Fig. 37) and the following diplosyllables. This is shown in more detail by amplitude spectra determined on individual diplosyllables, three of which are illustrated (Fig. 39). Diplosyllable 1 exhibits a strong peak at 4.1 kHz, which is not so clearly developed in the following diplosyllables. These spectra also exhibit strong frequency bimodality, most clearly developed in diplosyllable 1, due to the reduced amplitude of frequencies between ~6-9 kHz. Diplosyllables 2 to 10 show the same amplitude spectra as those of the illustrated diplosyllables 5 and 10. This bimodality cannot, however, be simply correlated with differences in the frequencies observed in the initial and dominant second hemisyllables themselves, the spectra of which tend to extensively overlap in their frequency ranges.

Amplitude spectra of multiple (10-11) chirp phrases (Fig. 40a, b), from different insects, exhibit

a complex of peaks centered at approximately 5-6.5, 7-8, 9-10, and 10.5-11.8 kHz, with minor peaks at 12-13 kHz. The breadth of the peaks reflects the multiplicity of lower frequency side bands, correlated with the complex array of amplitude modulations arising from the various diplosyllable and hemisyllable structures, listed in Table 6. The broadband character of the main array of frequency peaks is significant, and compares with the calling song spectra of both *G. bolloni* and *G. carnarvonensis*. These major frequency peaks cannot be readily related through possible higher frequency sidebands. They are thought, in line with previous interpretations made above for the other described *Graminitigrina* species, to reflect changing sound radiation patterns. This would be consistent with the observed very rapid frequency changes observed in the expanded waveform plots (e.g. Fig. 38a).

5B. Ratchet Song

This comprises a sequence of discrete diplosyllables (clicks) with constant repetition rate within a given song sequence, these varying between 22-37 Hz (mean 27.5 Hz). Each diplosyllable has a closely similar structure to those of the calling song (Fig. 38b, c) with a low amplitude initial hemisyllable and dominant second hemisyllable, whose time parameters are also similar (Table 6). One minor difference is the existence of a distinct pulse doublet in the dominant second hemisyllable (Fig. 38c), somewhat similar to those seen in the dominant hemisyllables of *G. carnarvonensis*.

Amplitude spectra of ratchet songs (Fig. 40c, d) indicate a blurring of the clearly defined frequency peaks that are seen in the calling songs, with a consequently broader continuity of emitted frequencies, although within the same overall frequency envelope as the calling songs. The spectra are characterised by a dominant sideband which precisely corresponds, within each specific recorded ratchet song, to the click repetition rates. If the distinct frequency peaks of the calling songs are the result of changing sound radiation characteristics of the insects, then the more evenly distributed frequency structure of the ratchet song suggests the damping of these abdominal movements.

5C. Interpretation

The songs of *G. triodiae* has marked similarities to those of *G. carnarvonensis*, and to a lesser

extent those of *G. bolloni*. The calling song differs from that of *G. carnarvonensis* in terms of both the number of diplosyllables within each chirp phrase, and the occurrence of low amplitude initial hemisyllables followed by high amplitude second hemisyllables, the reverse of that seen in the songs of *G. carnarvonensis*. These pulse structures of *G. triodiae* represent an apparently atypical feature within Australian cicada songs. The timbal structures of *G. triodiae* also differ from those of *G. carnarvonensis* in respect to the fusion of ribs 1 to 4 both ventrally and dorsally, the very weakly developed short ribs between ribs 1 to 4, and the very robust rib 4 and the short but robust rib 5 (compare Figs 11c, 13c). As the number of diplosyllables per chirp varies between 6 to 11, their production cannot be correlated with the sequential buckling of the individual ribs of either one or both timbals. Three possible explanations are put forward to relate the observed songs to observed timbal structures.

(a) Ribs 1 to 4 may be 'locked' and therefore buckle as a single unit. If correct, this could imply that each diplosyllable represents the buckling of one timbal, with the low amplitude initial hemisyllable related to buckling of rib 5, and the second, high amplitude hemisyllable the simultaneous buckling of ribs 1 to 4 as a unit. One problem raised by this explanation is the apparent lack of a peak representing the relaxation of the ribs, unless this occurs so rapidly as to be incorporated within each of the hemisyllable emissions. It also implies that successive diplosyllables result from alternating buckling of the timbals, possibly consistent with the variable diplosyllable numbers within the chirp phrases.

(b) Ribs 1 to 3 are locked as a unit during buckling and therefore buckle independently of the more robust rib 4. The initial low amplitude hemisyllable could thus represent the initial weaker buckling of ribs 1 to 3, followed by the buckling of rib 4 producing the stronger second hemisyllables. This further suggests that each diplosyllable represents the buckling of a single timbal, with alternate buckling of the two timbals producing the sequences of syllables within each chirp phrase. Again, this explanation does not account for the lack of relaxation peaks, unless these coincide with the hemisyllables, which seems unlikely due to the changing repetition rates of the diplosyllables.

(c) A third possible explanation is that the initial weak hemisyllables represent the simultaneous inward buckling of ribs 1 to 4 (± 5), followed by a

more 'explosive' relaxation to give the stronger second hemisyllable within each diplosyllable. Support for this explanation is found in the unusually robust rib 4 (\pm rib 5) which may provide an effectively stronger resistance (stiffness) to initial buckling, but once buckled, relaxation may occur very readily and strongly. The sequence of diplosyllables within a chirp phrase would seem again to require alternate buckling of the two timbals. This explanation is preferred.

DISCUSSION

The above documentation of the calling songs show that clear differences exist between the songs of each of the five described species. These include temporal arrangements of clicks and echemes, detailed syllable/macrosyllable structures and the resulting emitted frequencies. The calling songs of *G. bowensis* and *G. karumbae* show marked similarities in their gross temporal echeme and chirp structures, but differ clearly in their detailed syllable structures and song frequencies. The calling songs of *G. carnarvonensis* and *G. triodiae* also share marked similarities, both dominated by diplosyllables arranged within phrases without associated echemes. Again, detailed syllable structures are significantly different between these two species. The *G. bolloni* calling song is clearly distinct in the temporal structuring of its clicks and short echemes from the songs of *G. bowensis* and *G. karumbae*. Excepting *G. carnarvonensis*, all species share the ratchet song which is aurally very similar between each species, especially in the click repetition rates (see Tables 2 and 6 summarising song parameters of *G. bowensis* and *G. triodiae*).

An important feature of all the *Graminitigrina* calling songs is their wide range of emitted frequencies and the complexity of their amplitude spectra (Figs 23, 28, 32, 34, 40), this being especially marked for *G. bolloni*, *G. carnarvonensis* and *G. triodiae*. This aspect is particularly relevant in the context of the small size of these cicadas, noting the general correlation between decreasing body size and increasing song frequency (e.g. Bennet-Clark and Young, 1994). The broad frequency peaks seen within the various amplitude spectra reflect the extensive ranges of sidebands that are present. These further correlate with the wide ranges of amplitude modulations defined by the respective chirp and echeme structures illustrated in the respective waveform plots. As documented by Fonseca and Popov (1994) in the similarly small Portuguese cicada *T. gastrica*

Stål, such wide and complex frequency spectra reflect separate sound radiation structures, and their possible differential contributions to the click and short echeme song phases. These sound radiation structures are the timbals, tympana and abdomen, the latter most important in radiating lower frequencies. The other feature of note, documented in time expanded waveform plots of the calling songs of each *Graminitigrina* species, is the very rapid alternations of higher and lower frequency domains on time scales between ~0.1 to about 6 ms. These imply rapid and continuous body movements during singing, constantly changing the relative contributions of each sound radiating structure.

The wide range of frequencies emitted by the five described species, which effectively constitute multiple distinct frequency channels, produce marked ventriloquial effects in the field, which when combined with the cryptic colouration and very mobile behaviour of the adults, seem to provide effective defense strategies. The multiple frequency channels are also suggested to enhance the efficient transmission of songs in the dense grass in which the adults exist, the differing frequencies offsetting sound losses due to degradation by absorption, scattering, boundary reflections and refractions during sound propagation and ensuring that at least some frequency components will successfully propagate with minimum distortion. The higher frequency components also potentially facilitate sound localisation (Gerhardt and Huber, 2002).

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ADDENDUM

G. bowensis. Additional song documentation.

As listed in the paratype data for *Graminitigrina bowensis*, a series of specimens are included from Slaty Creek, approximately 25km southwest of Cloncurry, North West Queensland. This locality represents a significant extension of the known distribution of *G. bowensis* and represents an

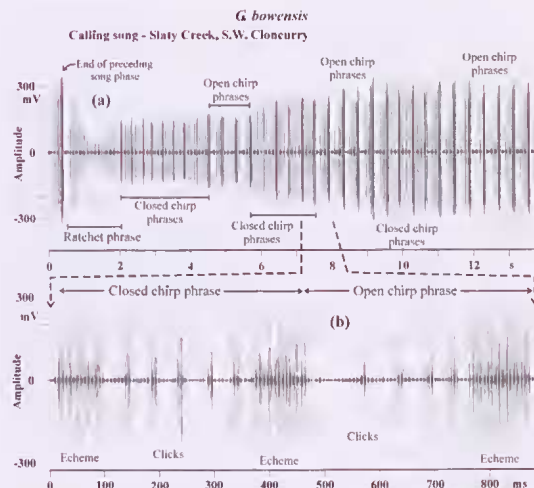


Figure A1. *Graminitigrina bowensis*. Waveform plots of calling song of the Slaty Creek population, approximately 25km southwest of Cloncurry, N.W. Queensland. (a) Three song phases recognised, comprising the ratchet, closed chirp, and open chirp phrases. The start of the plot shows the end of the preceding song phase, followed by the ratchet song, followed by the initiation of the new calling song phase at a new song post. The drop of amplitude in the ratchet song between the two song phases marks the flight between the two song posts, during which the ratchet song continues to be emitted. (b) Time expanded plot showing further details of click and short echeme structures of the closed and open chirp phrases. Based on field recordings, using a Marantz PMD660 digital recorder with Sennheiser K6/ME66 microphone.

outlying and very probably isolated population. No song data were available.

During 15-16 January 2008, AE visited this locality and digital field recordings were made of the songs from multiple cicadas that had newly emerged. Representative waveform plots are shown (Figs A1a, b) of the calling songs. Three distinct song phases are identified, comprising two types of chirp phrases plus a ratchet phrase which is emitted at the termination, in between flight, and at the commencement of singing at a new song post. The two types of chirp phrases are here referred to as closed and open chirp phrases. The closed type consist of pairs of short chirp echemes with four, rarely five, intervening clicks (each a single macrosyllable), emitted with nearly constant repetition rates. These are not specifically recognised in the songs described from the other localities, but do show some similarity to the pre-extended echeme chirp phases of the Bowen

population. The closed echemes are characteristic of the early phase of each song sequence, being more sporadically emitted between the open chirp phrases during the main segments of the calling song. The click repetitive rates are the same as observed in the ratchet song phrases. The open chirp phrases are very similar to the normal chirp phrases of the *G. bowensis* songs already described. They comprise most usually four (3-5) discrete clicks, each a single macrosyllable, which are emitted with progressively increasing repetition rates, and thereby merge into the following short chirp echemes.

For the closed chirp phrases, repetition rates range between 2.7 – 4.7 Hz, and 20-33 Hz for intervening clicks; short echeme widths are 0.06-0.12 s. For the open chirp phrases, the corresponding values are 1.6-3.3 Hz, 15-47 Hz,

and 0.10-0.14 s, the latter slightly shorter than observed at other localities (Table 2). Lengths of click macrosyllables in all song phrases range between 10.0-12.6 ms. Click repetition rates in the ratchet phrase are 19-26 Hz. These parameters are similar to those observed within the calling songs of this species from the other localities, listed in Table 2. The dominant frequencies are 10.9-11.3 kHz, slightly lower than observed in the other localities. The amplitude spectra are consistently asymmetric, however, with the maxima frequencies at 12.4-13.1 kHz.

In summary, the calling songs of the Slaty Creek Graminitigrina population are concluded to be consistent with that of *G. bowensis* from the type locality, although noting the additional development of the closed chirp phrases.